COMPUTATIONAL INTELLIGENCE IN HEALTHCARE PLANNING

Framework for Early-Stage Design, Compliance Validation & Collaboration

MSc GRADUATE DESIGN STUDIO

2025/26

HARI KRISHNAN SUBRAMANIYAN

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Framework for Early-Stage Design,
Compliance Validation & Collaboration

Thesis

for the purpose of obtaining the master degree
at Delft University of Technology

by the authority of the (names)
chair of the Board for (department name)

to be defended publicly on
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01.
IMPETUS

1.1 Personal Motivation

My motivation for this research stems from several years of professional experience focused on the early-stage design and medical planning of healthcare facilities. In this specialized field, I have observed that while the architectural process is defined by high stakes and immense complexity, the methodologies currently employed often struggle to keep pace with the rigorous demands of the sector. Specifically, I have found that traditional design workflows frequently fail to establish an intuitive or effective communication bridge between architectural planners and medical experts. This disconnect often leads to a feedback loop that is not only exhaustive and time-consuming but also lacks the agility required to adapt to rapidly evolving clinical requirements.

A central observation from my professional practice is the contrast between healthcare planning and the data-driven efficiencies seen in the real estate development sector. The real estate industry operates on a foundation of precise quantities and numerical performance, utilizing logical frameworks that are highly process-oriented. I believe there is a significant opportunity to translate this data-driven rigor to the healthcare typology. However, unlike standard commercial development, healthcare design requires a more nuanced integration of performance metrics, one that balances logistical efficiency with the qualitative aspects of patient care. This includes the parameterization of soft yet critical factors, such as daylight optimization, material health, and indoor environmental quality (IEQ), which add layers of complexity to the planning process.

Through this thesis, I seek to bridge these gaps by developing a systemic pipeline for generative design and collaboration. By integrating my technical learnings from the Building Technology program at TU Delft with practical insights from healthcare planning, my goal is to create a framework that reduces the potential for validation bias and manual error in the layout generation process.

This work represents a convergence of my deep interest in generative design workflows and the practical application of machine learning. By targeting the critical early-stage design phase, I intend to create a framework that does not merely automate tasks but provides a robust infrastructure for decision-making. Supported by the academic rigor of TU Delft and a global network of industry professionals across the Netherlands, India, and beyond, I aim to pioneer a scalable design pipeline, beginning with the complex requirements of healthcare and ultimately providing a blueprint for other specialized architectural typologies.

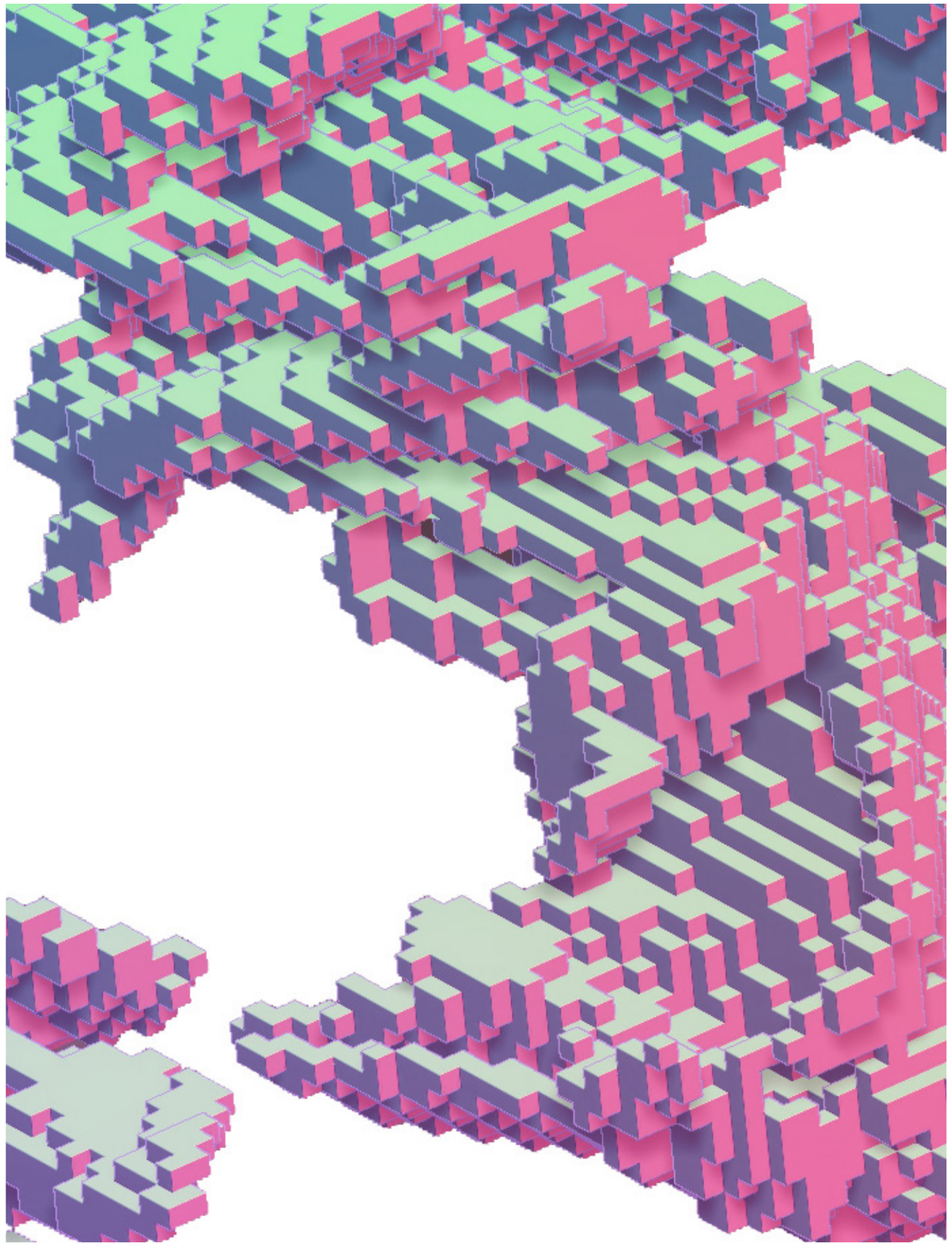


Fig.01 - Voxelscape - An Imaginary World of Program-less Volumes
Source - Author (2017)

1.2 Healthcare Planning

In contemporary healthcare design, it is standard practice to assemble a multidisciplinary team of medical experts, including doctors, clinicians, researchers, and facility managers, alongside architects and medical planners. This collaboration is essential to ensure that the facility's architecture and interior planning align with clinical requirements. Medical planning, in particular, is critical to the operational efficiency and effectiveness of a hospital, which directly correlates to the quality of patient care, environmental safety, and facility management.

The traditional process begins with a Request-For-Proposal (RFP), which outlines the hospital typology, medical specialties, projected patient volume, treatment categories, and administrative needs. Guided by these parameters, the medical planner and architect develop floor layouts that must conform to stringent guidelines and standards issued by local public health authorities.

Once the initial schematic department layouts are developed, they undergo a rigorous review process:

Iterative Reviews: Layouts are shared with medical experts for comments, typically through digital markups, usually on PDF exports of 2D drawings.

Collaborative Workshops: In-person sessions are scheduled where design teams and a medical panel such as doctors, facility managers, consultants, who cordially attempt to reconcile spatial configurations with clinical workflows.

Refinement: Planners then amend the designs to balance architectural intent, medical planning principles, and user experience.

Depending on the scale and complexity of the project, this cycle repeats numerous times during the early design phase. The goal is to optimize space planning, bed counts, and administrative flow; however, this cyclic nature often leads to significant project delays. This challenge is largely attributed to the current absence of a unified platform that allows design specialists and medical experts to communicate and make amendments in real time.

A notable parallel can be found in the residential and real estate sectors, where early-stage design for large-scale developments is increasingly automated. In those industries, algorithms optimized for cost-per-unit and density have successfully fast-tracked projects through data-driven workflows.

While the healthcare sector cannot be compared directly to residential typologies due to its higher nuance and critical safety requirements, it can adopt similar methodologies to improve efficiency. The current gap in technology presents a clear opportunity to develop novel workflows that act as a mediator between design specialists and healthcare professionals. By utilizing custom computational models, the process can be transformed from a series of disjointed revisions into a streamlined, stress-free collaboration.

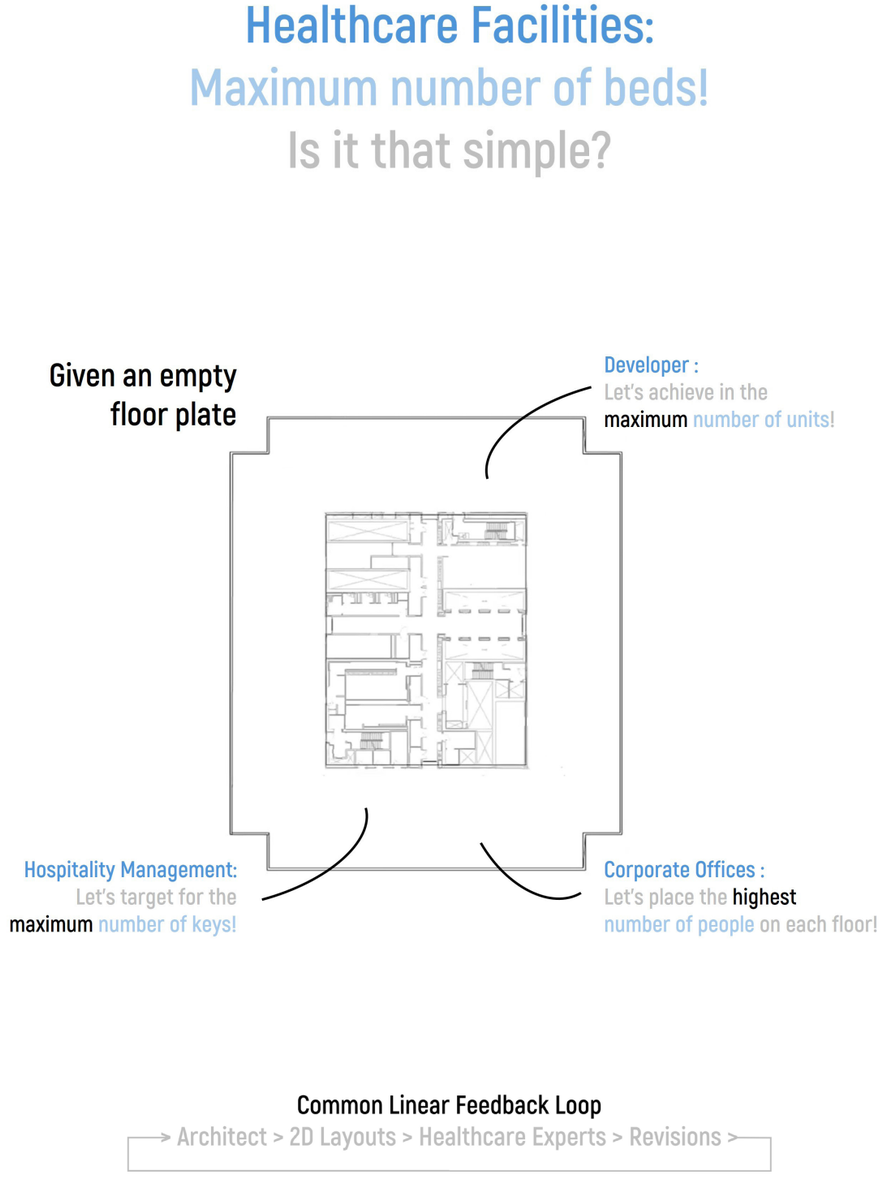


Fig.02 - Situations - Given an Empty Floor Plate
Source - Author (2025)

1.3 Design Technology

The landscape of Artificial Intelligence (AI) within the built environment has shifted with remarkable speed. As recently as 2024, the term AI was often utilized as little more than a marketing phrase; however, it has since become ubiquitous across the industry. While there have been positive developments, such as the implementation of Large Language Models (LLMs) and generative imagery to assist designers with visuals and walkthrough, the broader application of the technology remains fragmented. While highly data-driven Machine Learning (ML) workflows have been developed, they are frequently task-specific and remain largely inaccessible to a wider group of practitioners.

This rapid proliferation has also introduced significant challenges. The term AI is increasingly losing its core meaning, often to the extent that the sheer volume of generated content can be misleading to those unable to differentiate between actual architectural substance and AI-generated imagery. A significant amount of noise exists online, yet the built environment has yet to fully realize the benefits of these tools in a practical, systemic sense.

Furthermore, the accessibility of chatbot for coding and information gathering has led to a wave of new technologists focusing on the generation of AI content that may lack the depth necessary for real-world fruition. This trend of adopting the latest technology without a fundamental understanding of AI concepts often results in mediocre work, setting a concerning precedent for the technology's potential.

The true impact of AI in the built environment is more accurately found in applications involving empirical data and metrics, those that push the boundaries of the design process by using information to develop customized designs built on existing datasets or prior design knowledge. In principle, this is the core function of Machine Learning: an approach that is logical, grounded, and dependent on truth and rigorous training.
This represents a natural and logical extension of parametric and computational design, both of which are fundamentally rooted in logic and data-driven principles.

This thesis intends to explore AI-enabled workflows that provide tangible benefits to the user, whether they be designers, stakeholders, or clients. The objective is to utilize datasets and validated information to suggest design options and narratives, rather than creating a tool focused merely on visualization or superficial automation, a direction this research purposefully avoids.

Academic exploration at TU Delft across various topics related to the built environment has been instrumental in shaping this perspective. By examining computational design and machine learning applications, this research adopts a mindful approach to generation, considering both the natural and computational resources consumed in the process. This perspective encourages a critical stance toward the current expectations surrounding AI, focusing instead on its genuine possibilities for the future of architectural design.

Fig.03 - Search Trend Graph for AI in Computer Science (2020-2025)
Source - [trends.google.com (2025)]

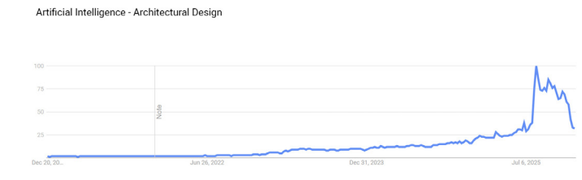


Fig.04 - Search Trend Graph for AI in Architecture (2020-2025)
Source - [trends.google.com (2025)]

Fig.05 - Examples of Digital Tools in Practice & Data Exchanges
Source - Author (2024)

02.
BACKGROUND

2.1 Context
2.1.1 Introduction

Extract from International Health Facility Guidelines (2025) - Part B - Planning Preliminaries

Health Planning
Healthcare Provision is the subject of a discipline known as Health Planning, defined as Planning for the Health of People. There are two branches to this discipline, Health Service Planning and Health Facility Planning.

Health Service Planning
This discipline relates to the research, analysis and calculation of health service demand, supply and gap for a given population catchment Every competent proposal for a health service starts with a Health Service Plan.

Health Facility Planning
This is the discipline which aims to design facilities and meet the health service gap. The outcome of this discipline is about the design and specifications for the construction of facilities or refurbishment and expansion of existing ones.

Fig.06 - Flowchart of Branches under Health Planning
Source - International Health Facility Guidelines (2025)

The complexity of healthcare planning necessitates a shift from purely intuitive design methods toward more robust, logical frameworks. Given the highly regulated nature of medical facilities, it is possible to establish a structured system to generate schematic zoning layouts for early-stage design optioneering. Such a framework does not replace the designer's intent, but rather provides a scaffold for it, ensuring that the fundamental spatial requirements are met before high-level aesthetic or formal decisions are finalized.

At the core of this approach is the synthesis of three critical data streams: detailed program requirements, stringent design standards, and complex functional adjacencies. By structuring these elements into a computational logic, the design process can move beyond manual drafting toward a more generative model. This allows for the rapid exploration of multiple design options, or optioneering, where each iteration is inherently compliant with the underlying medical planning logic.

Furthermore, the introduction of a data-driven workflow provides a more objective basis for communication between design stakeholders. In the traditional cycle of reviews and workshops, decisions are often slowed by the subjective interpretation of spatial configurations.

A systemic pipeline, backed by verifiable data, helps to:

Accelerate Decision Timelines: By providing real-time feedback on how changes to one zone affect the overall planning efficiency.

Garner Stakeholder Confidence: Using empirical data to justify planning decisions, thereby reducing the friction often found in multidisciplinary approvals.

Enhance Transparency: Creating a shared technical language that both architects and medical professionals can interpret and validate simultaneously.

By situating the research within this context, the project aims to demonstrate that the integration of computational tools is not merely a technical upgrade but a strategic improvement to the collaborative culture of healthcare design. This framework serves as the foundation for a more humane, efficient, and evidence-based design practice.

References - [(iHFG Part B, 2025)]

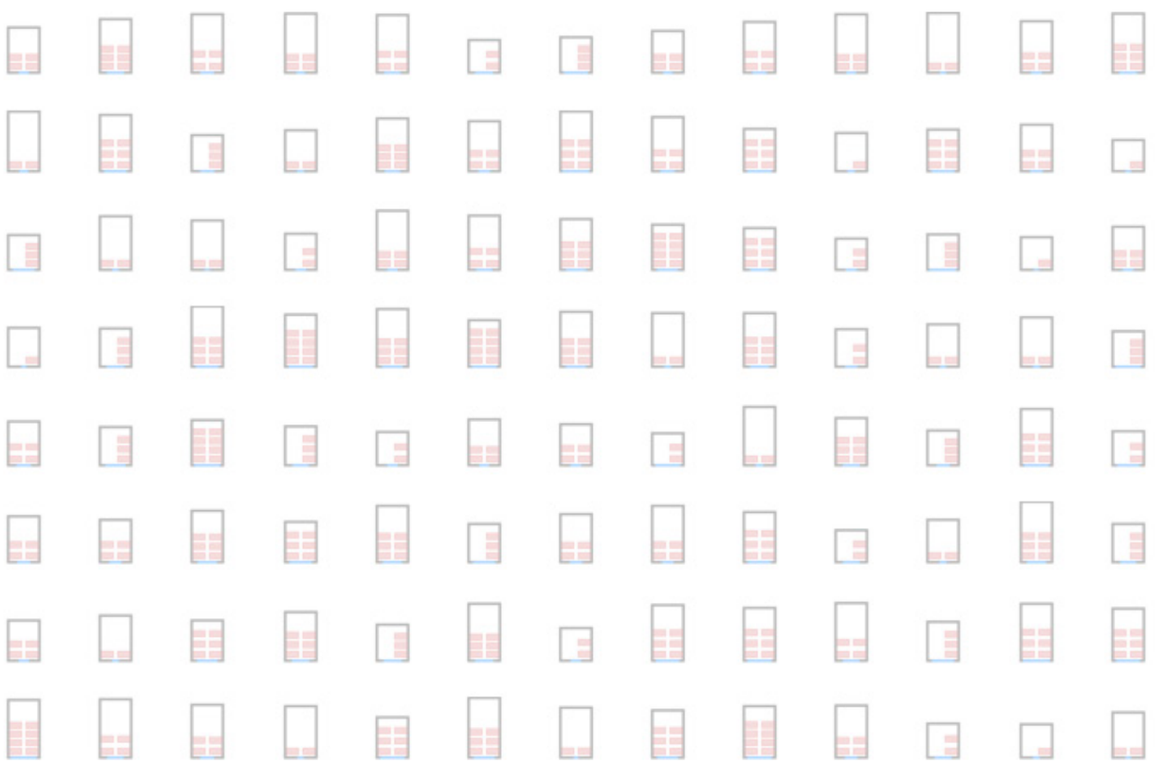


Fig.07 - Sample Surrogate Dataset of Hospital Bed Layouts
Source - Author (2025)

2.2.1 Relevance

Societal

From a societal standpoint, the fundamental purpose of Health Planning is the holistic well-being of the population. Healthcare represents the most vital infrastructure for any community; however, the global community recently faced a profound paradigm shift during the COVID-19 pandemic, which exposed critical vulnerabilities in this sector. The sudden upsurge of the virus placed the industry under unprecedented strain, creating an immediate, massive requirement for new hospitals and emergency facilities to be built at a speed previously considered impossible. This crisis demonstrated that when the transition from a Health Service Plan to a functional facility is hindered by inefficient, traditional design cycles, the primary consequence is a direct and dangerous delay in care delivery.

Since this global event, the landscape of healthcare design has fundamentally changed. A wave of new regulations and norms has emerged, focusing on infection control, flexible patient surge capacity, and enhanced ventilation standards. It is essential to acknowledge these changing times; methodologies for designing facilities must now be inherently adaptable and prepared for future crises while maintaining the highest standards of clinical quality.

This research is relevant to society because it seeks to develop a streamlined, AI-enabled workflow that reduces the time-to-market for hospitals. By accelerating the design process, the research ensures that communities, particularly in high-demand regions like India or developing European sectors, receive resilient, life-saving infrastructure without the typical years of procedural stagnation, making public safety the core driver of architectural production.

Professional

In the professional domain, the role of the architect and medical planner has become increasingly burdened by the sheer volume of technical data and the complexity of ever-evolving compliance codes. Currently, the design process relies heavily on static communication methods and disjointed feedback loops between clinical experts and design teams.

This reliance creates an environment of high friction and repetitive manual labor, where the tedious task of cross-referencing layouts against extensive regulatory datasets and project briefs consumes a significant portion of a professional's time. The core problem lies in this manual validation; it is not only time-consuming but prone to human error, often leading to costly revisions if discrepancies are discovered late in the project lifecycle.

This thesis identifies a critical opportunity to shift the professional workflow from manual documentation to informed, high-level decision-making. By advocating for the introduction of a computational mediator, the research explores how automation can handle the rigorous validation of technical standards and functional requirements in real-time.

This does not replace the professional; instead, it ensures that the designer and medical planner remain the primary authors of the vision, now empowered to focus on design quality, spatial experience, and patient safety. The scope of this research opens a new path for architectural practice where the hard data of facility planning is handled by intelligent systems, allowing professionals to navigate the complexities of modern healthcare infrastructure with greater precision and creative freedom.

Healthcare Industry

The healthcare industry is defined by exceptionally high capital expenditure and extreme technical complexity. From the perspective of private investors and government bodies, a healthcare facility is one of the most risk-intensive assets to develop. The industry operates under a landscape of stringent statutory norms and rigid timelines that are often at odds with the fluid nature of hospital design. Because these projects are of such a massive scale, any ambiguity in the early planning stages carries a compounded risk. The current industry struggle lies in the latency of information, where critical design flaws or clinical misalignments are often only discovered after significant resources have already been committed to the project.

The primary pain point for the industry is the devastating impact of design changes or revisions once the project moves past the initial planning stages. At this point, the technical infrastructure, such as medical gas lines, specialized ventilation, and structural reinforcement, is already deeply integrated into the design. A single revision to a clinical department can trigger a cascade of technical failures across multiple trades, leading to exponential cost overruns and severe delays in project completion.

This research addresses the urgent industry need for a more robust, data-driven methodology that can reconcile complex functional requirements with technical norms at the very start of the lifecycle. By exploring how to bridge the gap between design intent and industry standards earlier, this thesis opens up a vital scope for research into predictive validation, ensuring that the industry can deliver high-quality, high-standard facilities with greater financial certainty and operational resilience.

Fig.01 -
Source - Author (2025)

2.2 Research Framework

2.2.1 Problem Statement

What is the problem?
The core problem is with the time spent in refining layouts, to be in line with both the design standards and the spatial requirements of the client. Predominantly, a large portion of the time is spent in preparing the floor plans, ensuring compliance with norms. Following which, a sizeable effect on the timelines is caused by the back and forth with the healthcare professionals, in addressing their specific requirements, which may alter the original project brief.

Who experiences the problem?
The key players affected by this cyclic process are the designers or medical planners, who are often faced with revisions and constant changes, which require validation against the guidelines, which are often unique to the project's location and hospital typology. This sometimes results in missed deadlines, extended project timelines, or even in producing technically unsound solutions.

Where does the problem arise?
Since the majority of the design changes and coordination happen at the starting phase of the project, the maximum potential for a systematic workflow improvement is during the early stages of design. By implementing a robust framework, adaptable to change, there are benefits towards the timelines, financial, and efficiency aspects.

When does the problem occur?
The frequency of the problem is related to the number of design changes or updates that vmight be required for each floor plan, meaning that revisions are expected as long as the layouts are finalized, which is not a constant, but an unknown. This dynamic process requires a lot of planning ahead of time, and would benefit from an adaptive workflow, one that improves designers' experience and client communications.

Why is the problem important to solve?
The problem poses a challenge to the overall efficiency of a project, affecting timelines, communication gaps, excessive rework, and misaligned stakeholders. Addressing these issues through a holistic methodology will prove a productivity boost for design establishments and healthcare facilities. And, present a better solution for collaborative design, through data-driven design and higher success rates.

How are the users currently reaching their goals?
Presently, in a typical architectural practice, the design process is a closed loop, only involving the healthcare experts when required. While there are management-level advantages to this, like faster design decisions made, it often comes at the expense of time and countless revisions. It is a tried and tested method, but with the advent of LLMs and clients accustomed to consumer AI products, this workflow has room for improvement.

This research & thesis project aims to bridge the gap between an existing proven workflow and a future-ready methodology. As a proof of concept, the project aims to develop an end-to-end pipeline that demonstrates floor layout generation, design option compliance against standards, and a collaborative process between design and healthcare experts.

2.2.2 Research Objective

This research aims to develop and validate a computational, AI-mediated workflow for early-stage medical facility planning to resolve the significant time delays and inefficiencies caused by manual design refinement and compliance checking. The primary objective is to construct an end-to-end pipeline that leverages computational design for automated floor layout generation and incorporates a real-time validation model to ensure immediate adherence to both project requirements and regulatory standards.

Furthermore, the project will establish an adaptive and collaborative methodology by implementing an interactive framework that facilitates efficient, data-driven communication between medical planners and healthcare experts, minimizing the number of revision cycles. Ultimately, this research seeks to demonstrate a measurable increase in planning efficiency and accuracy by developing a proof of concept that transitions current architectural practices toward a streamlined, computation-driven approach to critical healthcare design.

2.2.3 Research Questions

How can an AI-driven framework automate the translation of unstructured information into compliant healthcare layouts to improve the design process and collaborative efficiency?

2.2.4 Conceptual Framework

The approach to research and literature review on the key topics related to the research question, will be classified into three domains - **Design, Data & Decision.**

Design
Healthcare Planning
Design Process
Zoning Layouts

Data
Design Standards
Area Statement
Department Adjacencies

Decision
Validation ML Model
Graph Neural Networks
LLM + Design Space

Fig.01 -
Source - Author (2025)

2.2.5 Research Areas

Main Research Question	Topical Research Questions	Research Areas	Expected Outcomes
How can an **AI-Driven Framework**	How can a **rule-based optioneering framework** be effectively developed to **automatically generate** initial medical facility floor layouts that **satisfy primary zoning**, spatial, and volumetric constraints derived from a **project brief**?	Text Information to Graph Networks Graph to Room Geometry	**Design Pipeline** - Text to Graph - Graph to Geometry
automate the translation of **Unstructured Information**	How effectively can a pre-trained **text interpreter** model **convert unstructured project documentation** and **design guidelines** into structured data for use as parameters in a **real-time validation model** for **floor plan compliance checking**?	Design Guidelines & Standards Client Brief & Area Requirements	**Process Automation** - Formatting Unstructured Data - Generate Area Statements - Build Proximity Charts for Graphs
into **Compliant Healthcare Layouts**	To what extent can **Graph Neural Networks (GNNs)** be utilized to **generate and validate healthcare layouts** by **cross-referencing topological department proximities** against **formatted facility standards**?	Proximity Diagrams & GNNs Schematic Department Zoning Layouts Design Validation Model (Comparing Graphs)	**Generative Design & ML Pipelines** - Spatial Relationships using GNNs - Schematic Zoning Layouts - Graph Comparison (Calibration)
to **Improve the Design Process**	What is the **measurable impact** of integrating a real-time, AI-driven **compliance validation** model on the time required for medical planners to **refine floor layouts** and **achieve adherence** to established **design norms**?	LLM-Integration for Referring to Documents (RAG) Client-side Text Interaction with Layout (Revisions)	**LLM RAG Components** - Develop LLM-RAG Pipeline - Natural Language Processing - Revisions to Graph/Geometry
and **Collaborative Efficiency** ?	How does the implementation of the **interactive interface enhance collaborative efficiency** by accurately **interpreting textual user inputs** from healthcare experts and translating them into **constrained, compliant layout modifications**?	Rhino.Compute Web Interface (Dynamic Layouts) Feedback to Users (Live Validation) Stakeholder Communication (Dashboard)	**User Interface & Collaboration** - Altering Zoning using Text Inputs - Custom UI with Rhino Viewport - Shared Workspace & Exporting

Fig.01 - Keywords in Research Question & Overview of Topics
Source - Author (2025)

03.
DOMAIN RESEARCH

3.1 Literature Review - Design
3.1.1 Overview of Healthcare Planning

Healthcare Facilities

Healthcare facilities represent a critically important architectural typology, serving as the physical infrastructure for services of major importance to communities, particularly in resource-limited or emergency settings. These are inherently complex buildings with rigorous functional and technical requirements that directly influence the quality of medical care. The physical environment is a key determinant of clinical outcomes; while inadequately designed facilities can contribute to adverse events and healthcare-associated infections, a properly designed facility improves the treatment process, reduces stress for patients and staff, and ensures cost-effective operational efficiency (Coelho, 2013).

Global Market and Demand

Global healthcare spending is on a sharp upward trajectory, projected to grow at a 4.7% CAGR to reach $10.75 trillion by 2029 (The Business Research Company, 2025) with the US expected to grow by 4.9% CAGR, reaching $5.22 trillion by 2032 (SNS Insider, 2025). This surge, driven by post-pandemic recovery and aging demographics, manifests differently across regions: while the United States faces rising service costs, emerging markets like India prioritize the rapid supply of new infrastructure to meet population growth. In contrast, European markets focus on the technological modernization of existing facilities to adapt to shifting medical requirements.

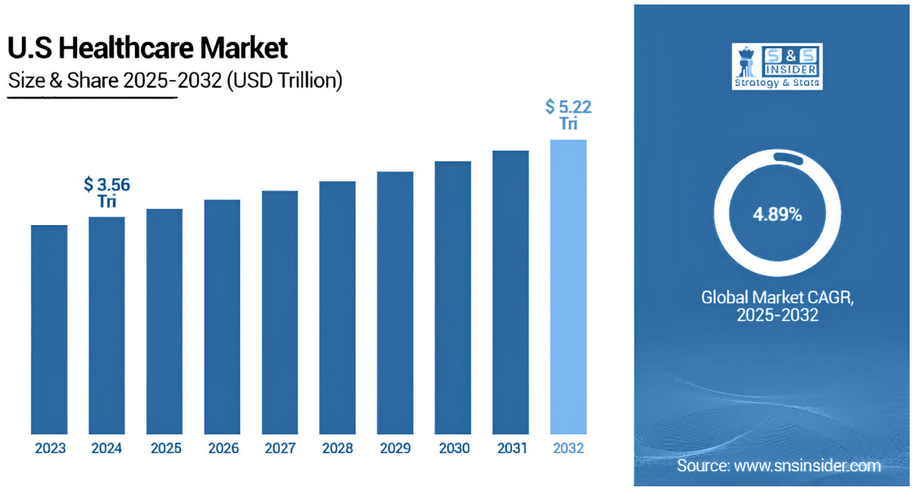
Simultaneously, the industry is transitioning from centralized hospital models toward decentralized, lower-cost settings such as ambulatory centers and home-based care. This shift, enabled by digital health tools, demands that architectural practice becomes more agile and diverse. Given that demand consistently outstrips resources, navigating high capital expenditures requires a transition to data-driven, process-oriented workflows. Such methodologies ensure facilities are context-specific and delivered with the speed and precision that traditional manual processes currently lack.

The Need for Robust, Data-Driven Workflows

The growing demand for healthcare services requires a rapid and reliable supply of medical facilities. However, the full project cycle, from assessment and feasibility to technical design and construction, often takes more time than expected. Traditional workflows can be exhaustive and time-consuming, usually lacking a common platform for real-time communication between designers and medical experts (Coelho, 2013).

A transition toward a more process-oriented and data-driven workflow is essential to bridge this gap. Utilizing logical frameworks, similar to those proven efficient in the residential and real estate sectors, can help manage the complexity and volume of healthcare data. By adopting methodologies that utilize actual data and metrics, the industry can develop customized designs built on prior knowledge and truth-based training, rather than relying solely on intuitive or repetitive manual processes. Such a robust infrastructure for decision-making ensures that facilities are not only built faster but are also clinically validated and optimized for safety and efficiency.

References -
(iHFG Part B, 2025), (Coelho, 2013), (The Business Research Company, 2025), (SNS Insider, 2025)



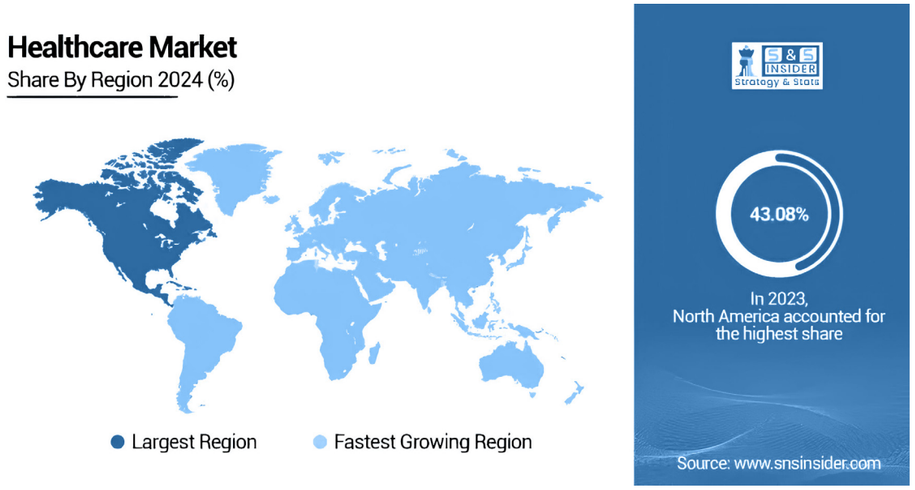


Fig.01 -
Source - Author (2025)

3.1.2 Stakeholders

The planning and design of healthcare facilities is a complex undertaking that requires a multidisciplinary approach, involving a diverse range of stakeholders. Each group brings specific priorities and expertise, making effective communication a prerequisite for a successful project outcome.

Based on industry standards and international guidelines, these stakeholders are generally categorized into three primary groups:

Clients & Funding Bodies

The client represents the entity initiating the project and is responsible for the overarching vision, funding, and long-term viability of the facility. These typically include:

Private Investors and Hospital Groups: Driven by market demand and operational efficiency, these clients often focus on Health Service Planning to identify service gaps in specific catchment areas (iHFG Part S, 2023).

Government and Public Authorities: Responsible for public health infrastructure, these entities focus on accessibility and meeting the needs of a wider population demographic, and may cater to a specific domain of care such as cancer care or paediatrics.

Non-Profit Organizations (NGOs) and International Agencies: Organizations that focus on providing healthcare in resource-limited settings or emergency contexts, where the design must balance technical rigor with extreme logistical constraints (Coelho, 2013).

Consultants & Medical Experts

Successful healthcare facilities are not designed in isolation; they require the continuous input of those who will operate within them. This group provides the clinical truth that informs the design parameters:

Medical Professionals: Doctors and nursing staff provide essential insights into clinical workflows, patient safety, and the human factor of medical care.

Facility Managers: They offer expertise on the long-term maintenance, logistics, and technical infrastructure required to keep the facility operational.

Researchers and Specialized Consultants: These experts assist in Role Delineation, ensuring the facility is equipped to handle the specific levels of clinical complexity required by the Health Service Plan (iHFG Part B, 2025).

Designers & Technical Specialists

The design team translates the data-driven requirements from the service plan into a physical environment. This group includes:

Medical Planners: Specialists who act as a bridge between clinical needs and spatial design, ensuring that adjacencies and departmental flows are optimized for medical efficiency.

Architects: Responsible for the structural, aesthetic, and environmental quality of the space, including critical soft factors such as daylighting and material selection.

Interior Designers: Critical in establishing the quality of space, which plays a major role in patient healing and well-being. Interior design is also accountable for providing a safe environment for clinical functions, such that a hygienic surrounding is maintained, with minimal effort.

The lack of a common platform for these groups to communicate effectively is a noted challenge in the industry. As the complexity of medical planning grows, the role of a mediator, represented in this research by an AI-enabled validation model, becomes essential to align the varying expectations of these stakeholders in real time.

References -
[iHFG Part B, 2025], [iHFG Part S, 2023], [Planning and Design of Health Care Facilities, Coelho, 2013]

Fig.01 -
Source - Author (2025)

3.1.3 Design Process

The design process for healthcare facilities is a highly structured journey that translates a community's health needs into a functional built environment. Unlike many other architectural typologies, the healthcare design process is characterized by a great deal of preparation that must occur long before any formal drafting begins (Coelho, 2013).

This process is traditionally divided into three major phases: Pre-Design, Design, and Post-design.

Pre-Design: The Foundation of the Brief

The initial phase focuses on defining the parameters of the project. This starts with the Health Service Plan, which determines the demand and clinical scope (iHFG Part S, 2023). Following this, a Project Brief is developed, which includes several critical technical documents:

Schedules of Accommodation (SOA): A comprehensive list of every room required, including its quantity and area (iHFG Part B, 2025).

Functional Planning Units (FPU): Groups of rooms that work together to perform a specific clinical function, such as an Operating Suite or Emergency Department. (iHFG Part B, 2025).

Role Delineation (RDL): Determining the complexity and capability of the services provided (e.g., a Level 3 vs. Level 6 hospital), which dictates specific design standards (iHFG Part B, 2025).

Design Phase: Synthesis and Iteration

Once the technical brief is established, the design phase follows a cascading level of detail, from the macro to the micro scale:

Site & Master plan Development: Assessing the site context, zoning, and long-term expansion potential.

Concept & Schematic Design: Establishing Zoning and Adjacencies by mapping the Flow of People and Flow of Goods to ensure clinical efficiency (Coelho, 2013).

Technical Documentation: In this stage, the first draft layouts are generated. By referring to the Room Data Sheets (RDS) and Room Layout Sheets (RLS) from the iHFG, planners translate the abstract requirements of the Schedules of Accommodation (SOA) and Functional Planning Units (FPU) into spatial configurations. These initial drafts must simultaneously account for individual room standards and the complex departmental adjacencies required for medical safety (iHFG Part B, 2025).

References -
(iHFG Part B, 2025), (iHFG Part S, 2023), (Planning and Design of Health Care Facilities, Coelho, 2013)

Post-design: Validation and Operation

The process does not conclude with the completion of construction. The post-design phase is critical for ensuring that the facility actually performs as intended:

Commissioning: A systematic process of ensuring that all building systems (medical gases, HVAC, sterilization units) perform interactively according to the design intent and operational requirements.

Post-Occupancy Evaluation (POE): An assessment of the building's performance in use. This provides a feedback loop for future projects, identifying whether the designed adjacencies and workflows truly support clinical efficiency and patient care (Coelho, 2013).

Maintenance and Lifecycle Management: Ensuring the facility adapts to technological advancements and clinical shifts over time.

The transition between these phases is inherently iterative. Workshops and reviews with medical experts occur at every milestone. However, because this process often relies on traditional manual drafting and static reviews, a significant gap remains in how effectively design specialists and healthcare professionals can communicate spatial changes in real time.

This research identifies the Pre-Design & Design Phase as an area with high potential for automation. By applying a logical, process-oriented framework, it is possible to fast-track the transition from an SOA to a validated schematic layout, ensuring that the design remains grounded in the rigorous data defined during the pre-design phase and optimized for the post-design reality.

Fig.01 -
Source - Author (2025)

3.1.4 Review, Revisions & Authorship

Once the initial schematic layouts are drafted, the project enters a critical phase of iterative review and validation. This stage is characterized by a multi-layered exchange of information between the design team, the client, and various expert panels, each bringing a specific lens to the spatial configuration.

Clinical Expertise & Functional Inputs

The schematic layouts are shared with an expert panel of healthcare professionals, including clinicians, doctors, and nursing staff, who review the design from a practical, clinical flow point of view. As noted in the iHFG Part S (2023), health services must evolve in line with changing practices and technological advancements. These stakeholders provide high-level subjective inputs derived from years of professional practice that standardized guidelines may only address broadly.

These experts often request changes to the proximity & zoning, hence the inputs can be classified into:

Adjacencies: Refining the proximity between clinical spaces to minimize staff travel time or enhance patient safety during transitions, ensuring the Flow of People remains efficient (Coelho, 2013).

Spatial Sizing: Adjusting the size of specific rooms to accommodate specialized procedures or larger clinical teams than initially projected in the standard Schedule of Accommodation (SOA).

Specialized Equipment: Identifying the need for additional medical technology or support infrastructure unique to the hospital's specific clinical model, often necessitating changes to the Room Data Sheets (RDS) (iHFG Part B, 2025).

Technical Insights from Facility Management

Parallel to the clinical review, the facility management team provides a technical audit of the layout. As emphasized in the iHFG Part B (2025) and Coelho (2013), the facility must be secure, maintainable, and logistically sound.

This team often requests modifications or additional spaces that are not explicitly detailed in general design guidelines:

Logistics and Movement: Detailed insights into patient movement, waste management pathways, and the separation of clean and dirty flows to prevent cross-contamination.

Security and Private Zones: The identification of required private zones, high-security areas (such as psychiatric intensive care or secure mental health units), or restricted access corridors.

Building Services and Maintenance: Ensuring adequate provision for plant rooms, service shafts, and maintenance access points to support the building's lifecycle and technical infrastructure.

References -
(iHFG Part B, 2025), (Planning and Design of Health Care Facilities, Coelho, 2013)

Mode of Communication

These inputs are typically conveyed through informal sketches, written reports, or digital markups on PDFs. The design team, composed of architects and medical planners, must then find an optimal solution that synthesizes these demands. This involves cross-referencing expert feedback with statutory norms, quality of space, and the original project brief.

Finding a balance between these two domains, the design and the clinical/technical, is the primary motive of this phase. However, as noted in the research impetus, this cycle is frequently exhausting and time-consuming. Despite being a tried and tested method, the fragmented nature of this communication often results in friction. There is a clear opportunity for a more intuitive process that helps stakeholders arrive at decisions meeting both hard criteria (standards and norms) and soft criteria (clinical intuition and operational experience).

Design Authorship

Throughout this iterative process, the authorship remains strictly with the designer or medical planner. While the process is highly collaborative, the designer is ultimately responsible for integrating these diverse change requests while ensuring the final output remains fully compliant with governing norms and the Role Delineation (RDL) framework (iHFG Part B, 2025).

This research seeks to address the inefficiency of this loop, exploring how AI-enabled workflows can assist the author in validating these complex, multi-stakeholder inputs in real-time, thereby fostering a more seamless alignment between design intent and clinical reality.

Fig.01 -
Source - Author (2025)

3.1.5 Project Stages & LOD

To navigate the complex transition from a clinical brief to a completed facility, the industry utilizes a standardized framework known as the Level of Development (LOD). This framework is further contextualized by the ISO 19650 standards, which provide an international foundation for managing information over the whole life cycle of a built asset. ISO 19650 defines the processes for information management, linking project stages with the Level of Information Need.

This ensures that the LOD, originally categorized by the American Institute of Architects (AIA), is not merely about geometric detail, but is a measure of the maturity and reliability of the data at specific milestones, indicating the degree to which project team members can rely on that information for decision-making (AIA G202-2013). The integration of LOD with traditional project stages is essential for healthcare projects, where the high volume of data must be managed through increasing layers of reliability.

Pre-Design (LOD 100)

At the earliest stage, the model represents the Conceptual Design. Here, elements are portrayed as generic masses or 2D symbols to signify their existence. In the context of healthcare, LOD 100 is used for:

Massing Studies: Establishing the building's overall footprint on the site.

Spatial Programming: Defining the approximate area, height, and volume of Functional Planning Units (FPUs) based on the preliminary Schedule of Accommodation (SOA).

Feasibility: Information at this stage is considered approximate and is used primarily for initial cost-per-square-meter estimates and site orientation.

Stage Deliverables - High-Level Medical Technology Report (iHFG Part Q, 2023)

Schematic Design (LOD 200)

As the project moves into Schematic Design, elements are refined into generalized systems. The model begins to take a more recognizable shape, with walls, floors, and major structural components outlined with approximate quantities, sizes, and locations. For a medical planner, LOD 200 is a critical milestone for:

Zoning and Adjacencies: Defining the relationships between departments.

Clash Detection (Initial): Identifying major spatial conflicts between architectural layouts and large-scale MEP (Mechanical, Electrical, Plumbing) requirements.

Stage Deliverables - Preliminary - Room-by-Room Equipment Schedule, Engineering Data Sheets (EDS), Room Data Sheet (RDS), Room Layout Sheets (RLS), Bill of Quantity (BoQ), Equipment Budget (iHFG Part Q, 2023)

References -
(Level of Development Specification, Part 1, BIM Forum), (AIA Digital Practice G202, 2013), (iHFG Part Q, 2023)

Detailed Design (LOD 300)

In the Detailed Design phase, the model transitions into a precise geometric representation. Elements are now defined with exact dimensions, specific orientations, and accurate placement within the project origin. This level forms the basis for construction documents and regulatory approvals. It incorporates:

Technical Compliance: Validation of the layout against Room Data Sheets (RDS) and specific Room Layout Sheets (RLS) from the iHFG.

External Coordination: Precise integration between architectural, structural, and medical gas systems.

Stage Deliverables - Revised - Room-by-Room Equipment Schedule, RDS, EDS, RLS, BoQ, Equipment Budget, Equipment Tender Specifications (iHFG Part Q, 2023)

Construction Documentation (LOD 350)

LOD 350 acts as a bridge between design and construction. It expands on LOD 300 by adding information about how an element interfaces with other building systems. In healthcare, this includes:

Support and Connections: Detailing how heavy medical equipment (e.g., MRI machines) is anchored to the structure.

Cross-Trade Integration: Precisely modeling the interfaces between different systems to ensure seamless on-site assembly.

Stage Deliverables - Final - Room-by-Room Equipment Schedule, RDS, EDS, RLS, BoQ, Equipment Budget, Equipment Tender Specification (iHFG Part Q, 2023)

Construction Stage & As-Built (LOD 400 & 500)

The final stages focus on the physical execution and long-term operation of the facility:

LOD 400 (Fabrication): The model contains sufficient detail for shop drawings and pre-fabrication, including specific part numbers and installation instructions.

LOD 500 (Operational/As-Built): The model is field-verified to reflect the actual conditions of the completed building. For healthcare providers, an LOD 500 model is an invaluable tool for Facility Management, supporting maintenance, lifecycle analysis, and future renovations

Stage Deliverables - Prepare Tender Package, Invite Tenders, Receive and Evaluate Received Bids, Award Letters/ PO Issuance, Review of Material Approval Submittals (MAS), Review of Shop Drawings & Pre-Installation Requirements, Coordinate Deliveries, Supervise Installation, Testing & Commissioning Coordinate Clinical & Technical Training, Hand-over, Pre-Operational Management Staff Training & Dry Runs (iHFG Part Q, 2023)

Late-stage revisions in healthcare projects carry severe consequences, as the cost of design changes increases exponentially once a project moves beyond Schematic Design (LOD 200). According to the MacLeamy Curve, the ability to influence positive design outcomes is highest during the early phases; by the time a project reaches Detailed Design (LOD 300), the structural and technical infrastructure is often too rigid to accommodate changes without causing significant financial waste and timeline delays. Effective communication and robust collaboration during these early stages are therefore critical to ensuring that the hard criteria of statutory norms and the soft criteria of clinical practice are reconciled before resources are committed to technical documentation.

This thesis directly responds to these early-phase design challenges by proposing a computational framework that acts as a mediator for multi-stakeholder input. By connecting disparate data streams, such as the Schedules of Accommodation (SOA) and Functional Planning Units (FPU), with the subjective feedback gathered in clinical workshops, the research introduces an AI-enabled validation process. This approach ensures that the transition from a conceptual brief to a physical layout remains grounded in iHFG standards and ISO 19650 principles, fostering a collaborative environment where design solutions are optimized for both clinical safety and project efficiency.

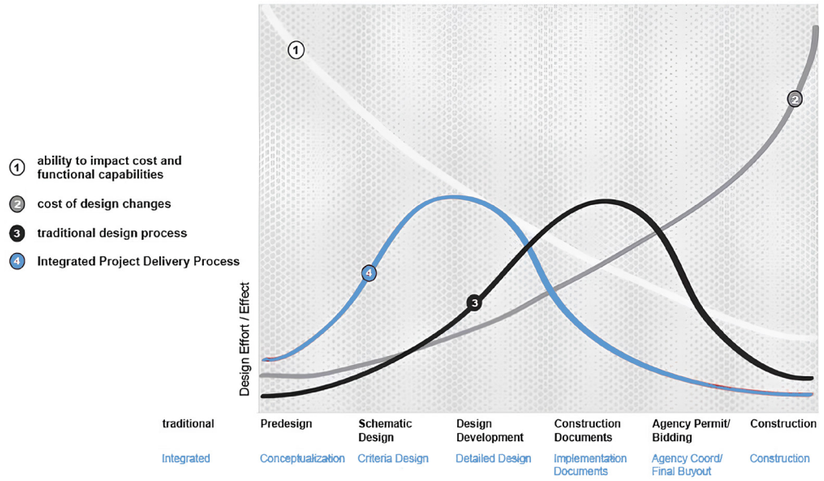


Fig.01 -
Source - Author (2025)

3.2 Literature Review - Data
3.2.1 Healthcare Design Standards

In healthcare architecture, design standards function as the primary data repository that bridges clinical necessity with physical space. To understand how these standards govern the built environment, we must break down the key information derived from the **International Health Facility Guidelines (iHFG)** manuals. The core of this framework is the **Functional Planning Unit (FPU)**, which provides a detailed blueprint for specific clinical departments or services.

As defined by the iHFG, FPUs are a key feature of health facility guidelines, providing detailed information on common clinical departments or services in hospitals and other healthcare settings (iHFG Website, 2026). They ensure that, regardless of the architect's experience, every department, from inpatient units to medical imaging, is built upon an evidence-based baseline.

Scalability and Service Levels

A critical strength of the FPU framework is its inherent flexibility across different project scales. In selected units, the schedules of accommodation are designed to describe a range of service levels or scenarios (iHFG, n.d.). This allows the data to be used to brief facilities ranging from small district hospitals through to complex tertiary hospital services (iHFG, n.d.). The specific complexity of these services is dictated by the Role Delineation (RDL), a framework that determines a facility's capabilities.

To manage this complexity, the iHFG manuals provide critical datasets that act as the technical backbone for the design. These will be discussed in detail in the coming sections:

Role Delineation Level (RDL) - The framework determining the facility's capability and complexity.
Functional Planning Unit (FPU) - The departmental building blocks of the hospital.
Room Data Sheets (RDS) - Detailed alphanumeric requirements for individual rooms.
Room Layout Sheets (RLS) - Standardized graphic representations of room configurations.

Relevance

For the purposes of this research, the FPU framework represents the ground truth data. The structured nature of this information provides the ideal foundation for developing a computational mediator. By utilizing the explicit rules found in the iHFG, specifically the adjacency logic in relationship diagrams and the area requirements in the SOA, this thesis explores the possibility of automating the validation of schematic layouts in real-time.

Furthermore, the importance of this study extends beyond a single manual; by dissecting the FPU structure, there is a clear possibility to develop similar or modified workflows based on this framework for other building typologies and various geographies. This would allow for a universal methodology where any set of complex technical norms can be translated into a digital validation loop, ensuring architectural compliance and quality across different global standards.

References -
(Health Facility Guidelines, Website, 2026)

Fig.01 -
Source - Author (2025)

3.2.2 Room Delineation Levels (RDL)

Role Delineation Level (RDL) is a fundamental framework in healthcare planning that describes the complexity of the clinical activities undertaken by a specific service (iHFG Part B, 2025). The RDL is chiefly determined by the presence and qualifications of medical, nursing, and other healthcare personnel who hold credentials compatible with the defined level of care. Consequently, these personnel and services dictate the requirement for specific facilities, equipment, and spatial configurations within the building (iHFG Part B, 2025).

The primary purpose of role delineation is to ensure that clinical services are delivered safely and are appropriately supported by adequate staffing profiles, minimum safety standards, and rigorous operational requirements (iHFG Part B, 2025). By establishing a consistent language, the iHFG provides health care providers, planners, and officials with a standardized tool for the planning, reviewing, and approval of health facilities (iHFG Website, 2026).

The RDL framework utilizes a scale ranging from 1 to 6 for each major clinical activity or support service (iHFG Website, 2026):

Level 1 & 2 (Primary): These levels provide low-complexity ambulatory care, spanning from single-practitioner GP clinics to polyclinics and day surgery centers supported by specialist practitioners.

Level 3 & 4 (Secondary): Addressing low to moderate complexity, these levels include inpatient and ambulatory services ranging from regional hospitals with minor surgery to general hospitals performing major surgeries and comprehensive clinical support.

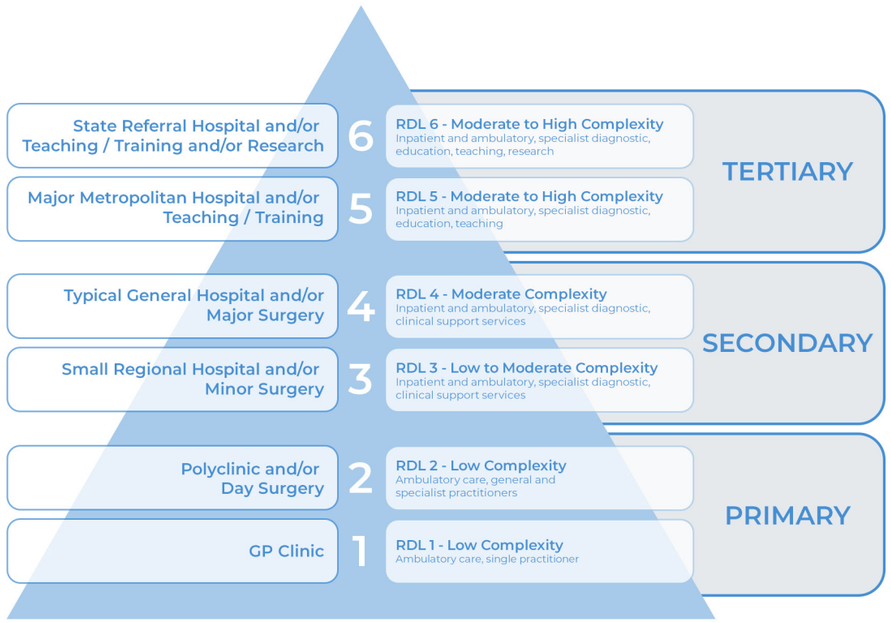
Level 5 & 6 (Tertiary): These levels represent high-complexity specialist care, including major metropolitan teaching hospitals and state referral hubs that integrate advanced diagnostics with intensive medical research and training.

While the RDL provides a comprehensive structure, it is important to note that the Guide confines itself to core services for hospitals and community healthcare facilities; services not explicitly identified follow the overall Role Delineation of the particular facility to which they apply (iHFG Part B, 2025). A hospital is generally deemed to be at a specific RDL when the majority of its clinical and support services align with that particular level (iHFG Part B, 2025).

In practice, the framework allows for nuanced classification. It is possible to determine the RDL of a specific component or an entire facility between two defined levels, such as between levels 4 and 5 (iHFG Part B, 2025). This intermediary classification is often applied to existing facilities that may have minor deficiencies in certain areas compared to the full definition of a specific role delineation level, yet still operate above the preceding level (iHFG Part B, 2025).

Relevance

In the context of this research, the RDL is the primary driver of the automated validation process. Since the RDL determines the specific Schedule of Accommodation (SOA) and Functional Planning Units (FPU) required, it serves as the initial data input for the proposed computational mediator. Understanding the RDL allows the system to identify which set of hard statutory rules must be applied to a schematic layout, ensuring that the design complexity always matches the clinical service level intended by the brief.



References - (iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

Fig.01 - Source - Author (2025)

3.2.3 Functional Planning Units (FPU)

FPU Constituents

Healthcare facilities are composed of distinct planning components, such as Intensive Care Units (ICU), Inpatient Pharmacies, or Main Entrances, each possessing unique functions and specific design requirements.

While commonly regarded as **departments**, the iHFG Part B (2025) utilizes the term Functional Planning Unit (FPU) to generalize across all types of functions and facility scales. This standardized terminology ensures that most clinical areas are referred to as Units (e.g., Emergency Unit rather than Emergency Room) to provide a consistent language for healthcare providers and planners (iHFG Website, 2026).

Each FPU serves as a key feature of health facility guidelines, acting as a data-rich repository that includes service descriptions, related policies, and operational planning. Furthermore, these units are designed for scalability; the schedules of accommodation can describe a range of service levels, allowing the data to be used for briefing projects ranging from small district hospitals through to complex tertiary hospital services (iHFG Part B, 2025).

For the purpose of this research, the individual components of an FPU represent the critical data inputs required for the computational mediator:

Functional & Planning Considerations: This component defines the technical logic of clinical flows, establishing which rooms or zones must be adjacent to ensure patient safety and staff efficiency (iHFG Website, 2026).

Functional Relationship Diagrams: These are example relationship diagrams that visualize the functional connections in a spatial format, serving as a precursor to formal architectural drafting (iHFG Website, 2026).

Schedule of Accommodation (SOA): A tabulated program list providing the exact quantity and area requirements (Sq. M.) for every room within the unit (iHFG Part B, 2025).

Schedule of Equipment (SOE): A comprehensive checklist of specialized medical technology and furniture required for the department to be clinically functional (iHFG Part B, 2025).

Future Trends: A section addressing emerging medical practices, technological shifts, and sustainability requirements that impact long-term spatial planning (iHFG Website, 2026).

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

3.2.3.a Functional & Planning Considerations

The Functional & Planning Considerations section of an iHFG manual provides the underlying logic that governs a department's layout. To illustrate the depth of data available to a designer, we can examine the Intensive Care Unit (ICU). This section moves beyond a simple list of rooms to define the operational rules of engagement that ensure patient safety and staff efficiency (iHFG Part B, 2025).

According to the iHFG Part B: Intensive Care Unit (2025), a designer can expect the following key data types from this section:

1. Operational & Level of Care Definitions
The guidelines first define the Operational Models based on the facility's complexity. For an ICU, this involves distinguishing between different levels of care (Level 1, 2, or 3), which dictates the nursing-to-patient ratio. For a planner, this is the first piece of hard data required to determine the size of nursing stations and the proximity of support staff to patient beds.

2. Planning Considerations
The ICU manual provides specific Planning Models, such as the Pod arrangement. It specifies that patient rooms should be grouped (e.g., in clusters of 6 to 10 beds) to share support facilities like clean and dirty utilities. This prevents the duplication of expensive infrastructure while ensuring that staff travel distances are minimized, a critical metric in life-saving environments (iHFG Part B, 2025).

3. Flow and Circulation Logic
The guidelines mandate the strict separation of flows to maintain infection control:

Clinical Flow: Direct, unobstructed paths for patient transfer from the Emergency Unit or Operating Unit.

Staff/Supply Flow: Internal corridors for the movement of sterile supplies and equipment.

Public/Visitor Flow: Controlled access points that allow family members to reach patient rooms without entering clinical work zones.

4. Observation and Line-of-Sight Requirements
A unique data point in the ICU section is the Requirement for Constant Observation. The guidelines specify that 100% of patient heads must be visible from a staff station or a decentralized observation point. This requirement dictates the use of glazed partitions and the specific orientation of beds, removing subjective design choice in favor of clinical safety.

5. Critical Functional Adjacencies
The manual establishes a hierarchy of adjacencies, categorizing them as Immediate, Convenient, or Desirable. For an ICU, Immediate access to the Operating Unit and Medical Imaging is a non-negotiable requirement. This data allows the planner to lock the department's position within the hospital's overall master plan during the earliest stages of design (iHFG Part B, 2025).

Fig.01 -
Source - Author (2025)

3.2.3.b Functional Relationship Diagrams

The Functional Relationship Diagram is the spatial translation of the clinical and operational requirements defined in the guidelines. Using the Intensive Care Unit (ICU) as the reference model, these diagrams visualize the topology of a department, establishing how various components must interact to ensure medical safety and efficiency (iHFG Part B: ICU, 2025, pg. 9).

For the designer, this diagram acts as a non-linear map that organizes the project data into two primary categories:

Program: Departmental Clustering

The diagram groups the individual rooms from the Schedule of Accommodation (SOA) into four distinct functional clusters to prevent cross-contamination and operational friction:

Clinical Zone: The high-acuity core containing patient bed spaces and immediate clinical support (e.g., Nurse Stations and Resuscitation bays).

Support Zone: Centralized areas for Clean and Dirty utilities, medication preparation, and equipment storage, positioned to minimize staff travel time.

Public Zone: The controlled interface for visitors, including the main entry airlock, waiting areas, and family counseling rooms.

Services Zone: Segregated areas for staff amenities (breakrooms, lockers) and service entries for the delivery of supplies and removal of waste.

Connectivity: Logic of Interaction

The diagram establishes the hard and soft constraints of the layout through specific connectivity rules:

Direct vs. Indirect Access: The lines of connection define which rooms must be physically adjacent (direct) versus those that merely require a clear proximity (indirect).

Access & Circulation: It dictates the Flow of People, specifically mandating the separation of the Patient Path of Travel from the Visitor Path, ensuring that families do not interfere with clinical emergencies (iHFG Part B: ICU, 2025, pg. 10).

Line of Sight: A critical requirement for ICU environments, where the diagram specifies the mandatory visual link between the nursing stations and the patient's head-end for constant observation.

References - *(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)*

Fig.01 -
Source - Author (2025)

Relevance

The combination of the descriptive text from the Functional & Planning Considerations and the topological rules of the Functional Relationship Diagrams is critical for the development of this research. Together, they provide the necessary data to formulate a comprehensive Proximity Matrix.

In the context of this thesis, this matrix serves as the source of truth for the computational mediator. By converting these human-readable diagrams into a structured matrix, the research can:

Model GNNs and Knowledge Graphs: Represent the hospital department as a series of nodes (rooms) and edges (adjacencies/flows), where the Graph Neural Network (GNN) can evaluate the health of a design layout.

Integrate Spatial Features: Augment the graph with additional features such as exact room dimensions, required areas (Sq. M.), and equipment quantities derived from the SOA.

Validation Parameters: Use the Knowledge Graph to instantly identify illegal connections or missing adjacencies, allowing the designer to receive real-time feedback on whether their layout complies with the iHFG's technical logic.

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

3.2.3.c Schedule of Accomodation (SOA)

While the previous sections define the logic and topology of a healthcare facility, the Schedule of Accommodation (SOA) serves as the primary quantitative dataset. It is a tabulated program that lists every room required for a specific unit, acting as the definitive bridge between the clinical brief and the physical architectural area (iHFG Part B, 2025). For a medical planner, the SOA is the master checklist used to ensure that the drafted layout meets the mandatory spatial requirements of the project.

Based on the iHFG framework and the structure of a standard SOA table, the following key parameters define the dataset:

Scaling by Role Delineation Level (RDL) and Capacity
The SOA is not a static document; it scales dynamically based on the facility's complexity and service needs. For instance, the iHFG provides specific SOAs for Intensive Care Units (ICU) at RDL Levels 4 to 6, often calculated for unit sizes of 8, 12, or 24 beds (iHFG Part B: ICU, 2025, pg. 19). This ensures that the quantity of rooms is proportionally adjusted to suit the specific scale of the clinical service.

Functional Grouping (Zoning)
To support efficient planning, the SOA organizes rooms into Functional Zones. Rather than a random list, rooms are grouped according to the discrete flow of patients, staff, services, and goods. Common groupings include the Clinical Zone, Support Zone, and Staff Zone, allowing designers to calculate the footprint of specific departmental clusters before they begin spatial drafting (iHFG Part B, 2025).

Room Codes and Standardized Room Types
Each entry in the SOA includes a unique Room Code and Room Name that links directly to a Standard Room Type. This standardization ensures that every planner uses the same definition for a Resuscitation Bay or a Clean Utility, preventing ambiguity in the technical brief.

Spatial Metrics: Area and Quantity
The core of the table provides the quantitative requirements for each room type:
Quantity: The specific number of rooms required for that unit size.
Recommended Area (Sq. M.): The minimum required area for an individual room.
Total Net Area: The sum of all room areas (the Sub-Total), which represents the functional footprint of the department.

Circulation Allowance and Total Departmental Area (TDA)
Because the area for internal corridors varies, with an Operating Unit requiring significantly more circulation space than an Administration Unit, the SOA provides a recommended Circulation Percentage. The Total Departmental Area (TDA) is the final target for efficient planning, representing the sum of all functional rooms plus the circulation multiplier (iHFG Part B: ICU, 2025, pg. 22).

Mandatory vs. Optional Designations
The SOA identifies which rooms are essential for clinical safety and which are Optional. This allows planners to make informed choices on scope creep during the review process, ensuring that the mandatory clinical core remains intact even if the project budget fluctuates.

Fig.01 -
Source - Author (2025)

Part B: Health Facility Briefing & Design
Intensive Care Unit

Intensive Care Unit – General at Role Delineation Levels 3 to 6

Room/ Space	Standard Component Room Codes	RDL 3 Qty x m² 4 Bed HDU			RDL 4 Qty x m² 8 Beds			RDL 5 Qty x m² 12 Beds			RDL 5/6 Qty x m² 24 Beds			Remarks
Entry / Reception														
Reception/ Clerical	recl-10-i recl-12-i				1	x	10	1	x	12	1	x	12	
Waiting	wait-15-i wait-20-i wait-30-i	1	x	15	1	x	20	1	x	20	1	x	30	1.2 m² per person; 1.5 m² per wheelchair
Waiting - Family	wait-20-i wait-25-i wait-50-i	1	x	20	1	x	20	1	x	25	1	x	50	
Meeting Room	meet-12-i meet-l-15-i				1	x	12	1	x	15	1	x	15	
Toilet - Public	wcpu-3-i	2	x	3	2	x	3	2	x	3	2	x	3	May share public amenities if located close
Gown Up/ Gown Down facility	gw-up-i similar gw-dn-l similar	2	x	6	2	x	8	2	x	10	2	x	10	Mandatory for parents and visitors
Patient Areas														
Patient Bay – High Dependency	pb-hdu-24-i	3	x	24	3	x	24	5	x	24	10	x	24	This is the open bay with curtain separation used for HDU
1 Bedroom – Intensive Care	1br-icu-25-i				3	x	25	5	x	25	10	x	25	This is the standard ICU room
Patient Bay - Critical (Enclosed); Class N Isolation	1br-icu-25-i similar	1	x	25	2	x	25	2	x	25	4	x	25	Negative pressure isolation room. locate away from Unit entrance
Anteroom	anrm-i	1	x	6	2	x	6	2	x	6	4	x	6	For negative pressure isolation rooms
Ensuite - Super	ens-sp-i	2	x	6	3	x	6	4	x	6	9	x	6	One ensuite for each isolation room. The balance shared by all other bedrooms at the ratio of one per 6 beds
Bay - Beverage	bbev-op-i bbev-enc-i				1	x	5	1	x	5	1	x	5	Optional, near Meeting Room/s
Change - Staff (Male/Female)	chst-10-i chst-20-i chst-25-i	2	x	10	2	x	14	2	x	20	2	x	25	Toilets, Shower and Lockers; size dependent on staffing numbers
Meeting Room	meet-l-15-i meet-l-25-i	shared			1	x	15	1	x	25	2	x	25	Quantity and size dependent on Service Plan
Office - Single Person, 12 m²	off-s12-i							1	x	12	1	x	12	Note 1; Director/ Service Manager
Office - Single Person, 9 m²	off-s9-i	1	x	9	1	x	9	1	x	9	2	x	9	Note 1; Unit Manager
Office - Single Person, 9 m²	off-s9-i	1	x	9	1	x	9							Note 1; Staff Specialists
Office - 2 Person, Shared	off-2p-i							1	x	12	1	x	12	Note 1; Nurse Educators, Staff Specialists, Clinicians
Office - Workstation/s	off-ws-i	1	x	5.5	2	x	5.5	4	x	5.5	8	x	5.5	Note 1; Registrars, Nursing, Secretarial
Overnight Stay - Bedroom	ovbr-i							1	x	10	2	x	10	Optional
Overnight Stay - Ensuite	oves-i							1	x	4	2	x	4	Optional
Staff Room	srm-15-i srm-20-i srm-35-i	1	x	15	1	x	15	1	x	20	1	x	35	May be shared
Store - Files	stfs-10-i										1	x	10	Optional, depends on record storage operational policy
Store - Photocopy/ Stationery	stps-8-i stps-10-i	1	x	8	1	x	8	1	x	10	1	x	10	
Sub Total		**364.5**			**570**			**790**			**1392.5**			
Circulation %		**40**			**40**			**40**			**40**			
Area Total		**510**			**798**			**1106**			**1950**			

Title - Department Classification

Table Headers - Department Classification

Room/ Space	Standard Component Room Codes	RDL 3 Qty x m² 4 Bed HDU			RDL 4 Qty x m² 8 Beds			RDL 5 Qty x m² 12 Beds			RDL 5/6 Qty x m² 24 Beds			Remarks
Waiting	wait-15-i wait-20-i wait-30-i	1	x	15	1	x	20	1	x	20	1	x	30	1.2 m² per person; 1.5 m² per wheelchair

Room Names | Cross-Reference Codes with RDS | Scale of Room Delineation Levels (RDL) | Additional Information

Zones - Functional Grouping

Spatial Metrics - Quantity x Area (Sq. M.)

Zone Gross - Area (SQ .M.) Before Circulation

Circulation Percentage - Additional Provision

Zone Total - Area (SQ .M.) Including Circulation

Relevance

For this research, the SOA provides the required quantitative feature set for the generative model. While the Functional Relationship Diagram provides the edges (connections) for a Knowledge Graph or Graph Neural Network (GNN), the SOA provides the node features.

By integrating the SOA into the proposed workflow, we get the following:

Assign Node Features: Each room in a Knowledge Graph can be assigned specific attributes such as Required Area, Quantity, and Functional Zone.

Compliance Checking: The system can compare a drafted layout in real-time against the SOA's TDA and circulation targets. If a designer drafts a room smaller than the iHFG minimum, the GNN can flag it as a non-compliant node.

Dynamic Scaling: Because the SOA is structured by RDL, the research demonstrates how a single Clinical Logic (the graph) can automatically re-calculate its area requirements if the project's RDL or bed count changes, drastically reducing manual re-calculation time.

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

Fig.01 -
Source - Author (2025)

3.2.3.d Schedule of Equipment (SOE)

In addition to spatial requirements, the iHFG provides a detailed Schedule of Equipment (SOE) for every room within a Functional Planning Unit. This dataset serves as a comprehensive inventory of all medical and non-medical items required for clinical functionality. According to the iHFG Part Q, 2025, equipment is categorized into three primary groups:

Group 1: Fixed equipment integrated into the building structure (e.g., scrub sinks, ceiling pendants).

Group 2: Major mobile equipment with significant utility requirements (e.g., patient monitors, ventilators).

Group 3: Minor mobile equipment and furniture (e.g., stools, waste bins).

The SOE provides technical specifications for these items, including their power, medical gas, and data requirements, which are typically used by medical equipment consultants and engineers to finalize utility point locations and structural loads (iHFG Part B: ICU, 2025).

Relevance

While the Schedule of Equipment (SOE) remains a vital component of the broader healthcare design lifecycle, it is not utilized as a primary data source for this research. This exclusion is based on the fact that the spatial requirements for all listed machinery and equipment are already integrated into the Schedule of Accommodation (SOA); the iHFG room sizes are pre-calculated to encompass both equipment footprints and essential clinical clearances, allowing the SOA to take precedence in spatial validation and architectural planning.

Consequently, this study remains focused on the departmental planning, specifically the spatial adjacencies and clinical flows. Granular technical specifications, such as voltage or gas flow rates, are considered secondary to the architectural layout and do not influence the core functional relationships or the computational proximity logic explored in this thesis. By prioritizing the SOA and FPU logic, the research maintains a clear focus on the architectural and operational synthesis required for high-level medical planning.

References - [(iHFG Part B, 2025)](), [(Health Facility Guidelines, Website, 2026)]()

7 Schedule of Equipment (SOE)

The Schedule of Equipment (SOE) below lists the major equipment required for the key rooms in this FPU.

Room Name		
Operating Room - General, room code (or-gn-i), Operating Room - Large, Room Code (or-la-i)		
Air flowmeter	Infusion pump: single channel	Pump: suction/ aspirator, surgical
Anaesthesia unit: standard	Infusion pump: syringe	Stool: adjustable, OR
Cabinet: storage, instrument, OR	Integration system: OR	Suction adapter
Control panel: surgical	Light: surgical, ceiling, with monitor arms & camera	Supply unit: ceiling, anaesthesia
Defibrillator: with monitor	Medication dispensing system: automated, anaesthesia	Supply unit: ceiling
Endoscopy tower: laparoscopy	Monitor: physiologic, operating theatre/ cardiac	Tracking system: instrument tray
Headlight: surgical	Operating table: electric, general	Warming cabinet
Hypo-hyperthermia unit: general	Oxygen flowmeter	
Infusion pump: rapid, blood/solution warming	Pump: suction/ aspirator, portable	
Operating Room - Cardiac, Room Code (or-ca-i)		
Air flowmeter	Infusion pump: rapid, blood/ solution warming	Pump: suction/ aspirator, surgical
Anaesthesia unit: standard	Infusion pump: single channel	Smoke evacuation system, surgical
Atherectomy System: rotational	Infusion pump: syringe	Stool: adjustable, OR
Cabinet: storage, instrument, OR	Integration system: OR	Suction adapter
Coagulation unit: ACT	Light: surgical, ceiling, with monitor arms & camera	Supply dispensing system: automated, catheter
Control panel: surgical	Medication dispensing system: automated, anaesthesia	Supply unit: ceiling, anaesthesia
Defibrillator: with monitor	Monitor: physiologic, operating theatre/ cardiac	Supply unit: ceiling
Electrosurgical unit: monopolar/ bipolar	Operating table: electric, general	Thrombectomy system: catheter
Headlight: surgical	Oxygen flowmeter	Tracking system: instrument tray
Heart/ lung bypass machine	Pump: intra-aortic balloon (IABP)	Ultrasound scanning unit: cardiac/ echo
Hypo-hyperthermia unit: general	Pump: suction/ aspirator, portable	Warming cabinet
Operating Room - ENT/ Ophthalmology, Room Code (or-ent-oph-i)		
Air flowmeter	Integration system: OR	Oxygen flowmeter
Anaesthesia unit: standard	Laser unit: surgical, holmium	Phaco system: ophthalmic
Cabinet: storage, instrument, OR	Laser: ophthalmic, YAG	Pump: suction/ aspirator, portable
Control panel: surgical	Laser: ophthalmic, retinal photocoagulation	Pump: suction/ aspirator, surgical
Defibrillator: with monitor	Light: surgical, ceiling, with monitor arms & camera	Stool: adjustable, OR
Diagnostic set: ophthalmic	Medication dispensing system: automated, anaesthesia	Suction adapter
Endoscopy tower: laparoscopy	Microdebridement unit: ENT	Supply unit: ceiling, anaesthesia
Headlight: surgical	Monitor: physiologic, operating theatre/ cardiac	Supply unit: ceiling
Hypo-hyperthermia unit: general	Operating microscope: ENT	Tonometer: IOP
Infusion pump: rapid, blood/ solution warming	Operating microscope: ophthalmic	Tracking system: instrument tray
Infusion pump: single channel	Operating table: electric, ENT/ ophth	Vitreoretinal system: anterior/ posterior segments
Infusion pump: syringe	Ophthalmoscope: indirect, binocular	Warming cabinet

Fig.01 - Source - Author (2025)

3.2.4 Room Data Sheets (RDS)

The Room Data Sheets (RDS) represent the most granular level of information within the iHFG framework. While the FPU and SOA define the department's structure and size, the RDS provides a detailed technical anatomy of every individual room type. These are written descriptions accessible through the official iHFG website under the Standard Components section. Each RDS is linked to a specific room type via the codes provided within the Schedule of Accommodation (SOA).

The information contained in each RDS is presented under the following categories:

Room Primary Information: Includes the baseline briefed area (Sq. M.), expected occupancy, a functional description of the room, primary clinical relationships, and any special room requirements.

Room Fabric and Finishes: Identifies the mandatory materials and finishes required for the room's ceiling, floor, walls, and doors, as well as specific glazing requirements.

Furniture and Fittings: Lists all objects typically located in the room that do not require service connections, ranging from medical to non-medical items.

Fixtures and Equipment: Includes all serviced equipment (medical and non-medical) and sanitary fixtures, alongside the required plumbing, power, and data connections.

Building Services: Indicates technical requirements for communications, power, HVAC (Heating, Ventilation, and Air-conditioning), medical gases, nurse/emergency calls, and lighting.

Relevance

In the context of this research, Room Data Sheets are not utilized as a primary data source because the current focus remains healthcare planning, specifically spatial adjacencies, clinical flows, and departmental blocking.

Since the RDS concentrates on the internal technical specifications of individual rooms rather than the systemic relationships between them, it falls outside the immediate scope of the computational mediator being developed.

However, this data remains highly relevant for future iterations of the research. Once the project moves beyond the schematic layout and into the detailed design phase, RDS data can be integrated to serve as a definitive reference for interior design and fit-out, providing essential details on materials, maintenance standards, and finish types.

Furthermore, it would assist in the precise placement and procurement of furniture and fittings, while ensuring technical integrity by confirming that the high-level layout can be successfully translated into a construction-ready model with all necessary building services accounted for. By identifying the RDS as a future integration point, this research acknowledges the eventual transition from foundational functional logic to detailed technical execution.

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

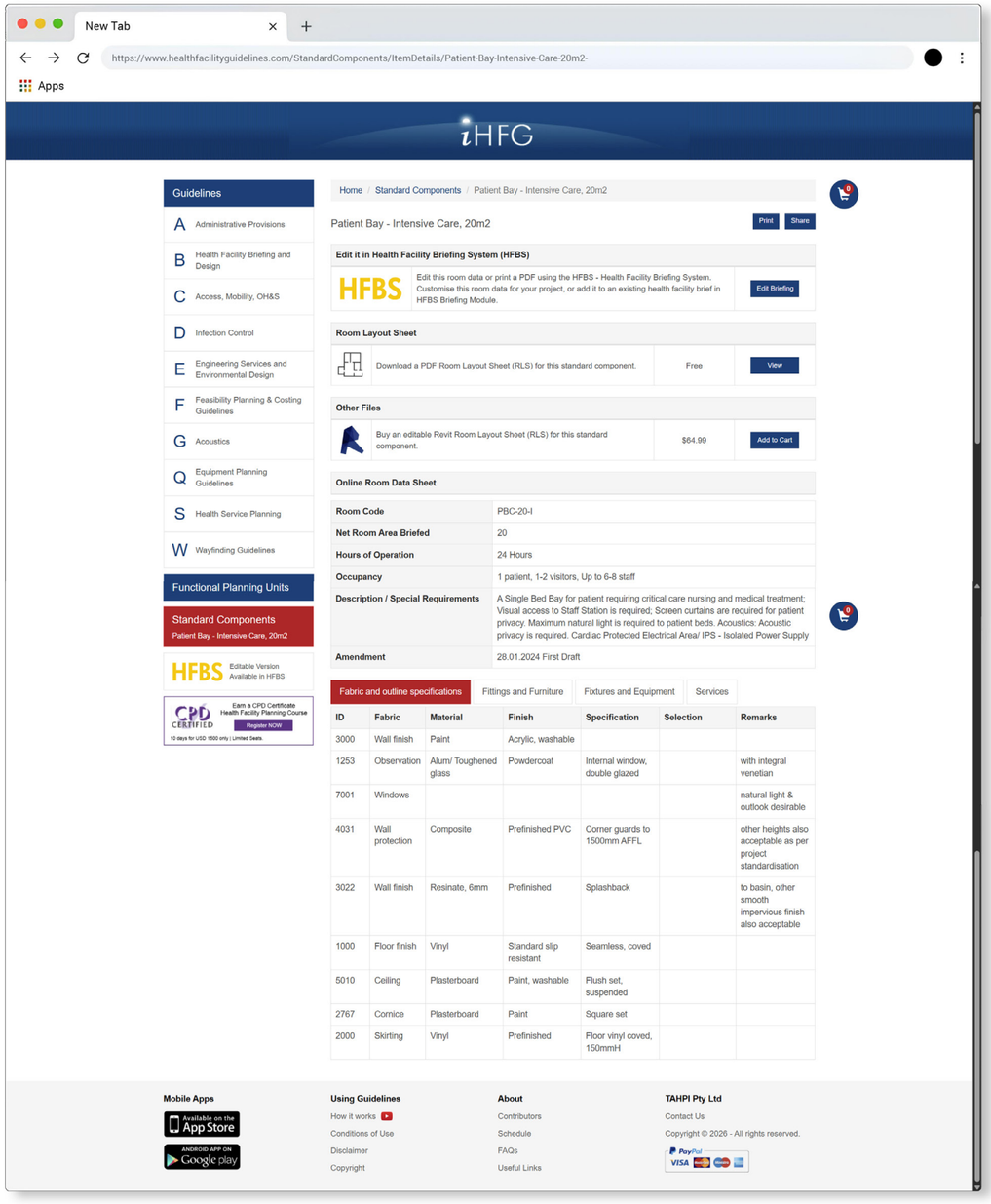


Fig.01 -
Source - Author (2025)

3.2.5 Room Layout Sheets (RLS)

The Room Layout Sheets (RLS) serve as the graphic counterpart to the technical briefing, providing standardized 1:50 scale drawings for typical and critical room types within a facility. According to iHFG Part B (2025), these sheets incorporate typical designs, including floor plans and at least four elevations that specify the installation heights of various elements. These drawings are available on the official iHFG website in both PDF and Revit formats, utilizing the same room codes as the RDS to ensure consistency across the documentation (iHFG Part Q, 2025).

The RLS illustrates the minimum acceptable design standards deemed to satisfy the guidelines, highlighting the relative location and empirical dimensions of critical components such as handrails, sanitary fixtures, bed screens, and service outlets for power, data, and medical gases (iHFG Part B, 2025). While these sheets provide a baseline, the guidelines allow for innovative planning alternatives as long as they comply with the core text, maintain the minimum floor areas specified in the SOA, and account for spatial adjustments, such as adding 2m² for each additional door beyond the minimum requirement (iHFG Part B, 2025).

Relevance

In the context of this research, Room Layout Sheets are not utilized as a primary data source because they represent a level of detail that exceeds the scope of the schematic design phase. The information provided in these sheets, such as specific working drawings, sample detailed layouts, and reflected ceiling plans, is most relevant for the later stages of design development and construction documentation.

Since this project focuses on the foundational healthcare planning, specifically departmental zoning and functional adjacencies, the granular interior coordination found in the RLS falls outside the current scope. These drawings remain a vital reference for medical equipment consultants and architects during the detailed design phases to ensure that the high-level functional logic is accurately translated into a physical, serviced environment.

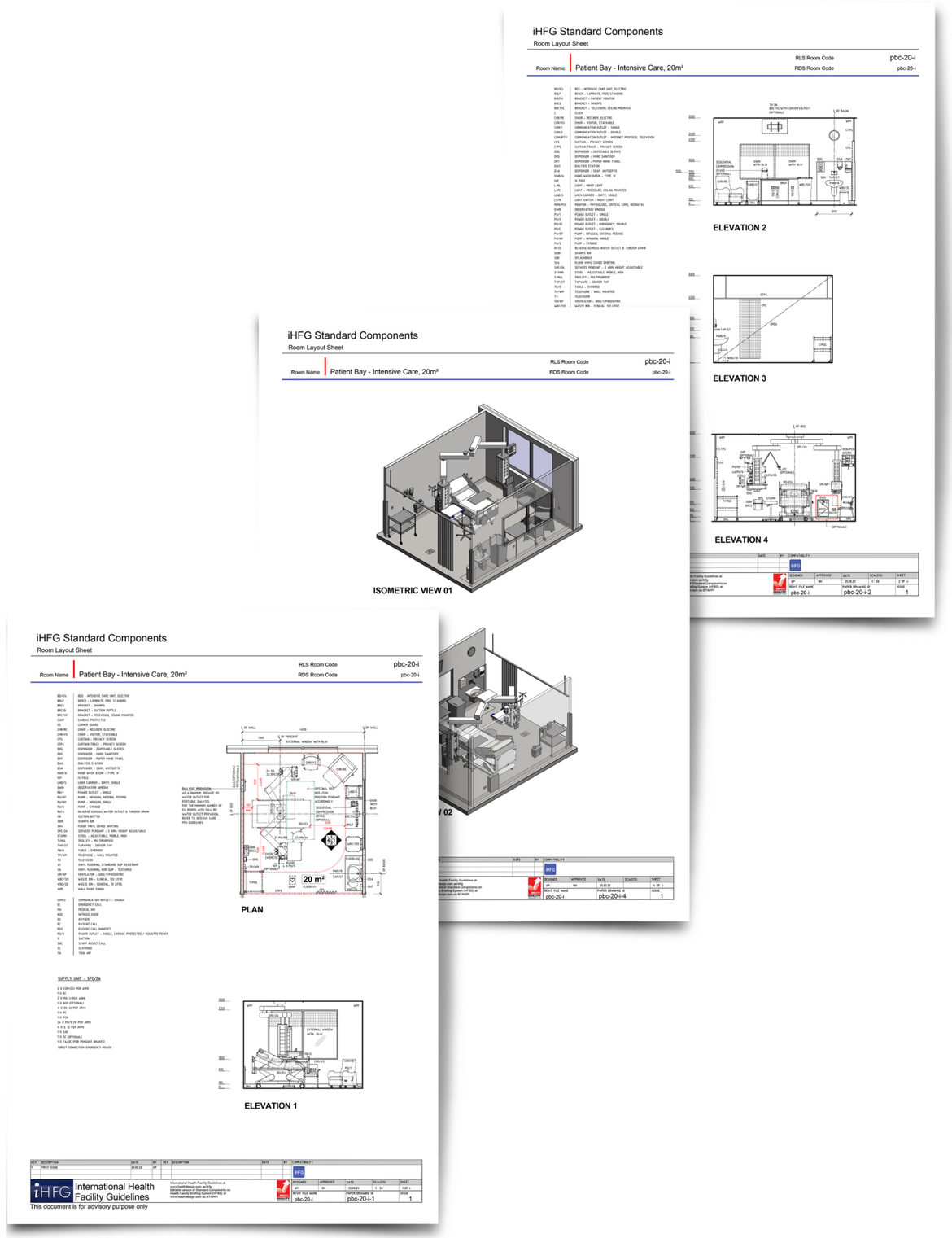


Fig.01 -
Source - Author (2025)

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

3.3 Literature Review - Decision

3.3.1 State of the Art

The transition from traditional computational methods to modern Artificial Intelligence (AI) represents a paradigm shift in how information is processed and decisions are formulated. At its core, AI is the simulation of human intelligence by machines, traditionally governed by Machine Learning (ML), a subset of AI focused on the use of data and algorithms to imitate the way humans learn, gradually improving accuracy over time.

This evolution is underpinned by Neural Networks, or connection systems, which are inspired by the biological neural networks of animal brains. These networks consist of layers of interconnected nodes that allow computers to recognize complex patterns in vast datasets, forming the engine behind contemporary generative tools.

Rise of LLMs

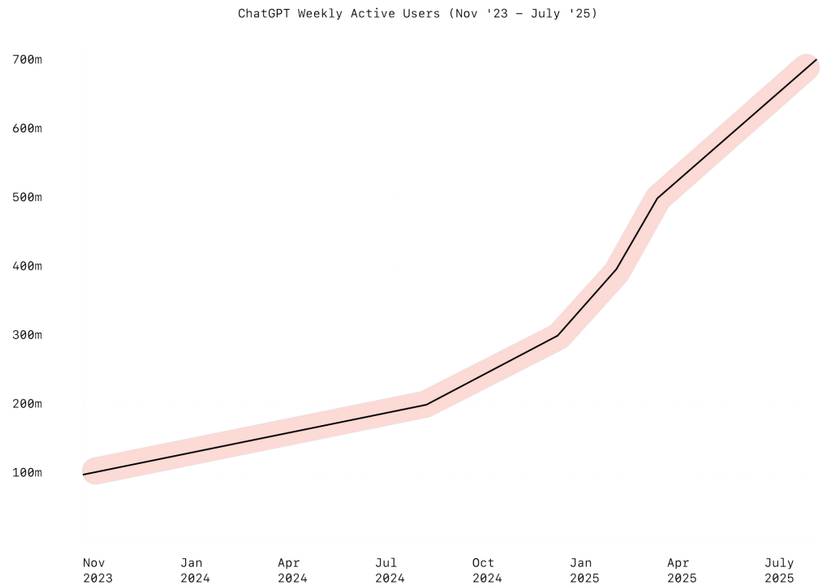
The most significant breakthrough for the general public has been in the field of Natural Language Processing (NLP). NLP enables computers to understand, interpret, and generate human language in a way that is both meaningful and contextually aware. This has culminated in the development of Large Language Models (LLMs), which are specifically trained to process and generate text at a level that is often indistinguishable from human output (Clusmann et al., 2023).

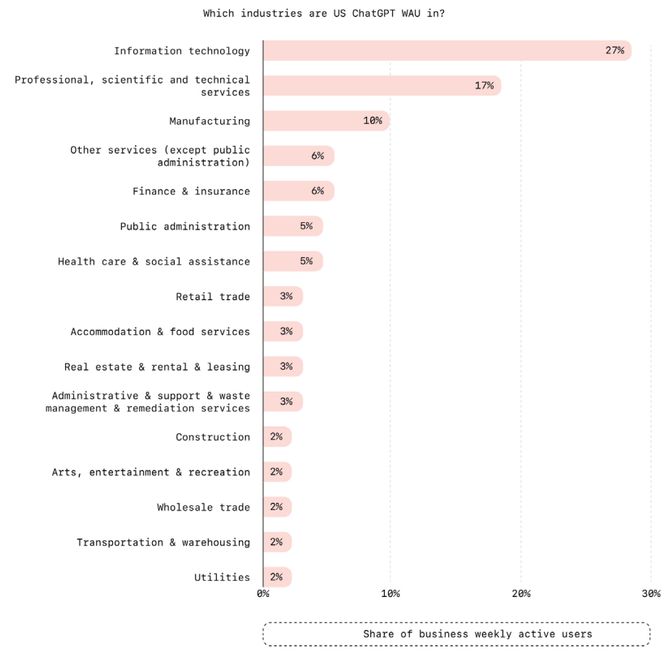
The widespread adoption of LLM-assisted writing and task management has been unprecedented. Following the public release of tools like OpenAI's ChatGPT in late 2022, usage surged across various sectors of society, including consumer complaints, corporate communications, academic research, and job postings (Liang et al., 2025). This democratization of AI means that common users, not just technical experts, are now utilizing tools such as Gemini, Perplexity, and ChatGPT to summarize information, paraphrase complex text, and automate mundane communication tasks (Mishra et al., 2024).

Trends in Usage

Current research indicates that LLMs have moved beyond novelty and are becoming integrated into the standard workflow of knowledge workers. A study of global clinical researchers and practitioners found that nearly 87.6% were aware of LLMs, with a significant portion already utilizing them for literature reviews, abstract screening, and manuscript drafting (Mishra et al., 2024).

Furthermore, surveys of knowledge workers across various domains indicate that people are increasingly utilizing these models to generate code, enhance text clarity, and manage complex datasets (Brachman et al., 2025). However, while these users recognize the productivity gains, there is a clear desire for a future where LLMs are more deeply integrated into their specific organizational data and personal workflows rather than acting as isolated chat interfaces (Brachman et al., 2025).





References - [(Liang et al; 2025), (Brachman et al; 2025), (Mishra et al; 2024), (Clusmann et al; 2023)]

Fig.01 -
Source - Author (2025)

3.3.2 Natural Language Processing (NLP)

3.3.2.a Large Language Models Integration

The integration of Large Language Models (LLMs) into the architectural workflow marks a shift from using AI as a purely generative text tool to utilizing it as a technical co-pilot within CAD environments. In contemporary research, this is increasingly achieved by bridging the gap between natural language and parametric software like Rhino and Grasshopper. Rather than manually drafting geometry, designers can now interface with the software through textual prompts, which are translated into executable code via LLM APIs (Saleh, 2025).

The methodology for this integration relies on a structured pipeline that converts human intent into geometric form. As demonstrated in the research by Saleh, the workflow typically utilizes a GHPython component within Grasshopper as the primary mediator. This component serves as the interface that hosts the LLM's API (such as OpenAI's GPT-4o or Google's Gemini), sending the user's design brief to the model and receiving a code-based response in return.

The specific language used for this translation is RhinoScriptSyntax (RSS). Because RSS is a Python-based library designed specifically for Rhino, it provides a stable and highly readable syntax for LLMs to manipulate. The process functions as follows:

Natural Language Input: The designer provides a prompt (e.g., Generate a layout for a 60m² apartment with two bedrooms and a central living area).

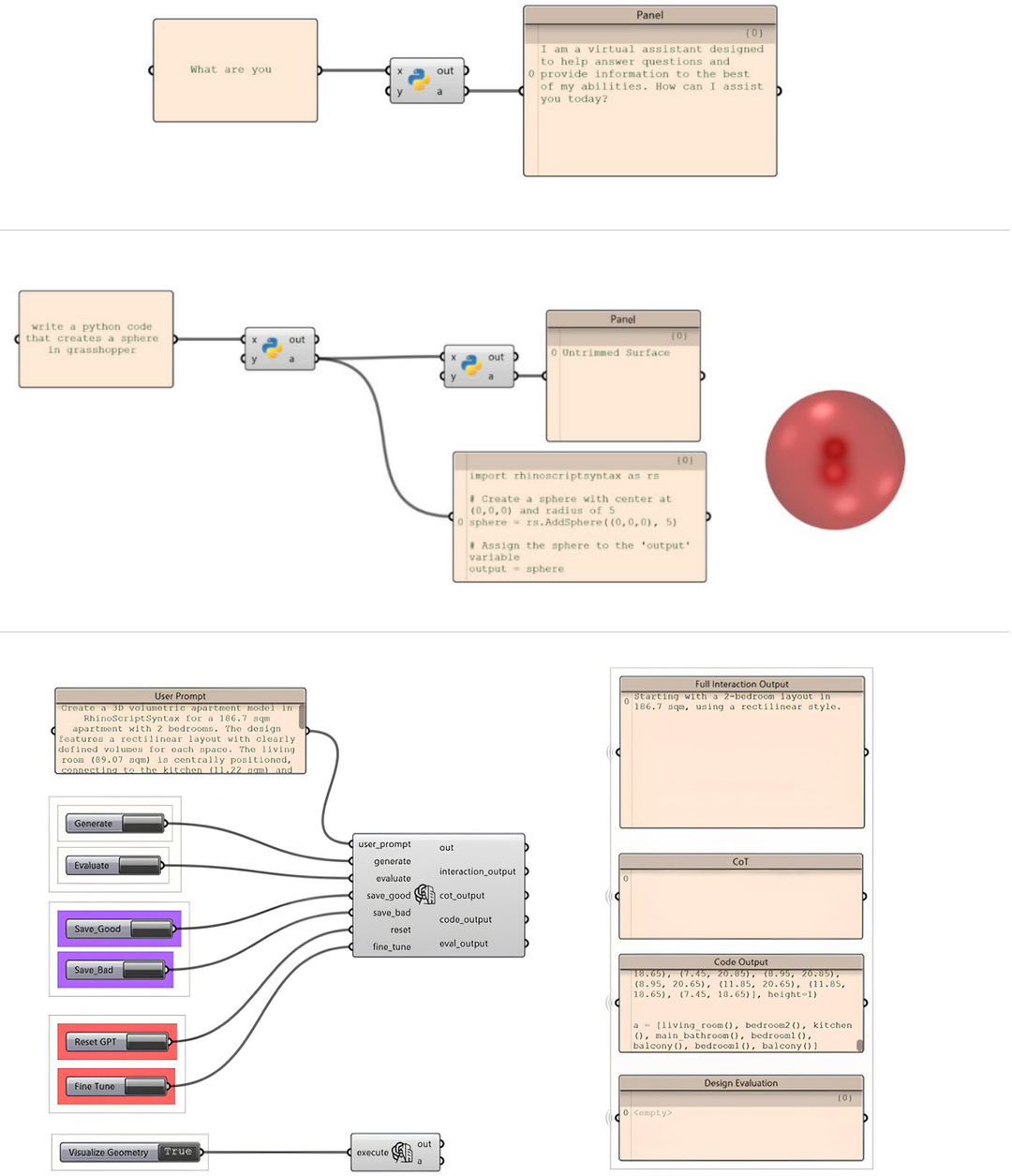
API Processing: The GHPython component sends this prompt, along with a system prompt that defines the rules of the geometric environment, to the LLM.

Code Generation: The LLM generates the corresponding RhinoScriptSyntax code required to draw the requested geometry (Saleh, 2025, pg. 58).

Geometric Execution: The GHPython component executes the returned script, instantly generating 3D volumes or layouts within the Rhino viewport.

A core advantage of this approach is its ability to support real-time, conversational design. In Saleh's prototype for generating data-driven 3D volumetric models, the assistant does not just produce a static output but allows for iterative refining. If the generated apartment layout does not meet the designer's expectations, a subsequent prompt can be used to tweak the dimensions or adjacencies, with the LLM rewriting the RSS code on the fly to update the geometry (Saleh, 2025, pg. 60).

This demonstrates that LLMs are capable of maintaining spatial awareness through code. By training or prompting the model to understand specific architectural constraints, such as room areas or functional relationships, the LLM acts as a computational mediator that bridges high-level human concepts with the rigid technical requirements of architectural drafting.



References - [(Laila Hany Mostafa Awad Saleh, TU Delft, 2025)]

Fig.01 - Source - Author (2025)

3.3.2.b Conversational Design

The implementation of the OfficeLayout LLM by Spacewalk represents a practical shift toward conversational design, where natural language acts as the primary input for complex spatial arrangements. The process is initiated by providing two core inputs: a natural language prompt describing the user's program requirements and a set of geometric boundaries, typically Rhino curves, which define the extents of the floor plan or individual room (Spacewalk Corp, 2024).

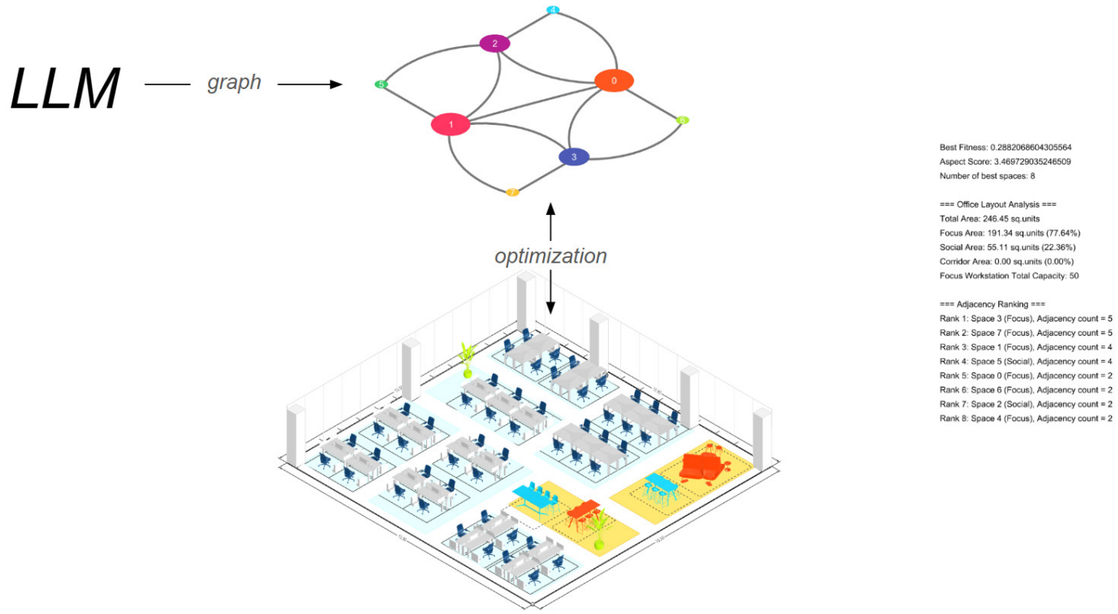
The backend architecture operates through a dual-stage pipeline that separates high-level reasoning from geometric execution. At the core of this pipeline is an LLM, that decodes the intent within the text prompt. Rather than drawing geometry directly, the LLM performs architectural reasoning to generate a symbolic representation of the layout. This output usually takes the form of a structured dataset, which identifies the required objects and their relative spatial constraints based on the user's description (Food4Rhino, 2025). This structured data is then processed by a solver that utilizes parametric algorithms like rectangle decomposition and bin-packing. This engine calculates the optimal coordinates and orientations for physical furniture blocks, ensuring they fit precisely within the provided Rhino curves.

A critical advantage of this workflow is its capacity for real-time, iterative adjustments. Because the system maintains a live connection between the LLM and the CAD environment via Grasshopper, users can provide follow-up prompts to refine the design. For example, if a layout needs more space between workstations or a different furniture configuration, a simple text update triggers the LLM to re-evaluate the symbolic constraints. The Placement Engine then instantly regenerates the furniture blocks to reflect these minor changes. This creates a dynamic feedback loop where the designer can fine-tune a professional layout through dialogue rather than manual drafting (Spacewalk Corp, 2024).

Relevance

Integrating LLMs into healthcare planning democratizes a traditionally exclusive process by allowing non-technical stakeholders, such as clinicians and administrators, to participate directly in spatial design. By utilizing natural language interfaces, these users can bypass the technical CAD barrier, moving beyond passive feedback like PDF comments or emails toward active co-creation. This shift ensures that expert clinical knowledge, the primary driver of hospital functionality, is captured accurately and instantly, preventing the misinterpretations that often occur when architects translate verbal or hand-sketched briefs into formal drafts.

Furthermore, the ability to generate and modify geometry through text-based prompts significantly reduces coordination friction and time-intensive feedback loops. Using a computational mediator that translates intent into executable code allows for on the fly adjustments, where a medical professional's verbal refinement instantly updates the physical layout. This real-time validation enables stakeholders to see the immediate spatial implications of their operational policies, ensuring that the final design is a precise, high-performance synthesis of the iHFG's technical standards and the practical realities of daily medical practice.



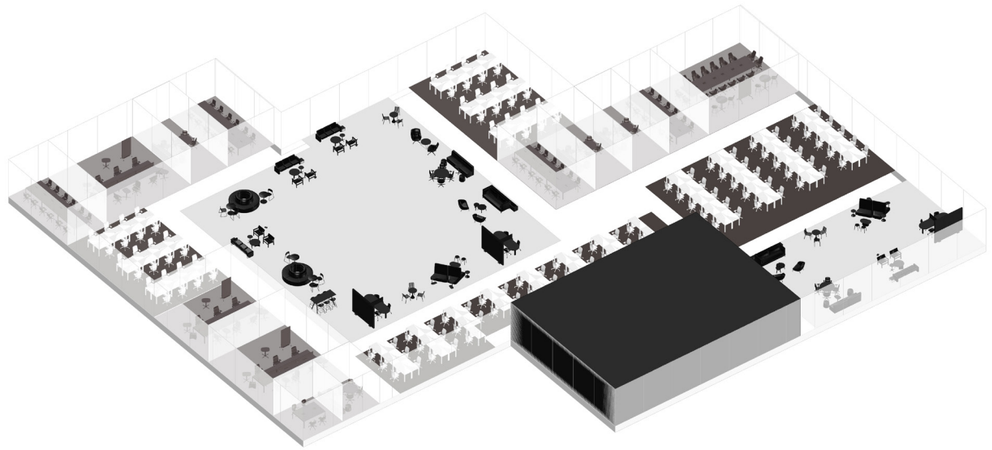


Fig.01 -
Source - Author (2025)

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

3.3.2.c Retrieval Augmented Generation (RAG)

Retrieval-Augmented Generation (RAG) functions as an architectural framework that bridges the gap between a Large Language Model's general reasoning and specific, high-stakes technical data. The logic behind RAG is essentially an open-book approach to AI: instead of relying solely on the frozen knowledge acquired during its initial training, the model first retrieves relevant chunks of information from an external, curated database, such as the iHFG healthcare manuals, before generating a response. This retrieval process uses embeddings to convert text into mathematical vectors, allowing the system to perform semantic searches that identify the most relevant technical clauses or spatial requirements. By prepending this retrieved context to the user's prompt, the LLM is no longer guessing based on probability but is instead synthesizing an answer from a specific, verifiable source (NVIDIA, 2024).

The fundamental advantage of RAG is most evident when comparing it to a standard LLM, which operates as a closed-book system limited by a knowledge cutoff and a tendency toward hallucinations when faced with granular technical queries. Without RAG, a model might confidently provide outdated or generalized healthcare planning advice that ignores specific regional standards or subtle clinical distinctions. Conversely, a RAG-enabled system fetches real-time data directly from uploaded documents, ensuring that every design constraint or proximity rule is grounded in the actual text of the guidelines. This allows the model to cite specific page numbers and provide the high-precision data required to build accurate Proximity Matrices and Knowledge Graphs, transforming the AI from a creative assistant into a reliable technical auditor.

Future-Ready & Local Hosting

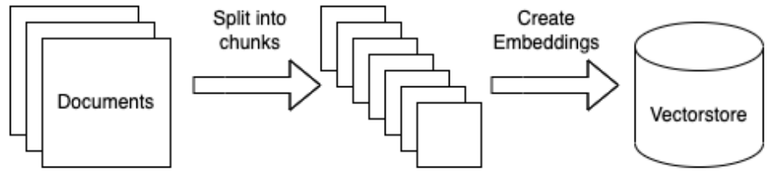
Frameworks like Ollama allow for hosting LLMs directly on local hardware, which is critical for the data privacy and security required in healthcare planning. Local hosting eliminates API costs, rate limits, and latency, creating a stable environment for iterative design. This decentralized approach also future-proofs the pipeline; as open-source models (such as Llama, Mistral, or Gemma) advance, they can be swapped into the existing architecture without a total system redesign.

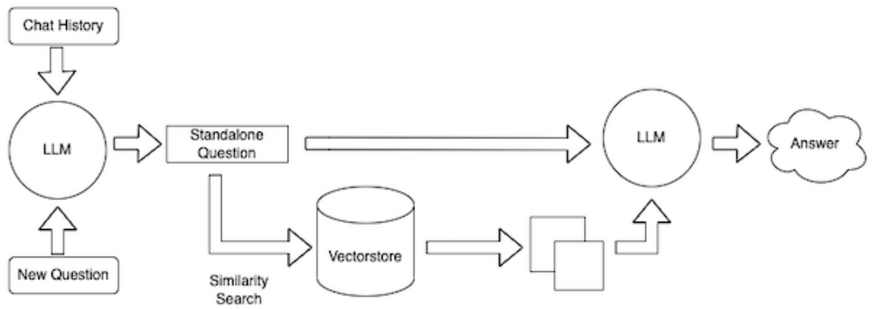
This pipeline remains resilient to shifting regulations and typologies. When standards like the iHFG are updated, the system can be refreshed by re-indexing the new dataset within the RAG framework or through local fine-tuning. This ensures the computational tool evolves alongside both AI advancements and changing healthcare requirements.

Relevance

For this research, RAG transforms static PDF guidelines into a dynamic, queryable Knowledge Base. It enables the computational mediator to identify room dimensions and clinical flows on demand, ensuring all spatial decisions are auditable. By grounding the generation process in the iHFG ground truth, the workflow guarantees that the resulting layouts are both technically compliant and mathematically validated.

References - [(iHFG Part B, 2025)](), [(Health Facility Guidelines, Website, 2026)]()





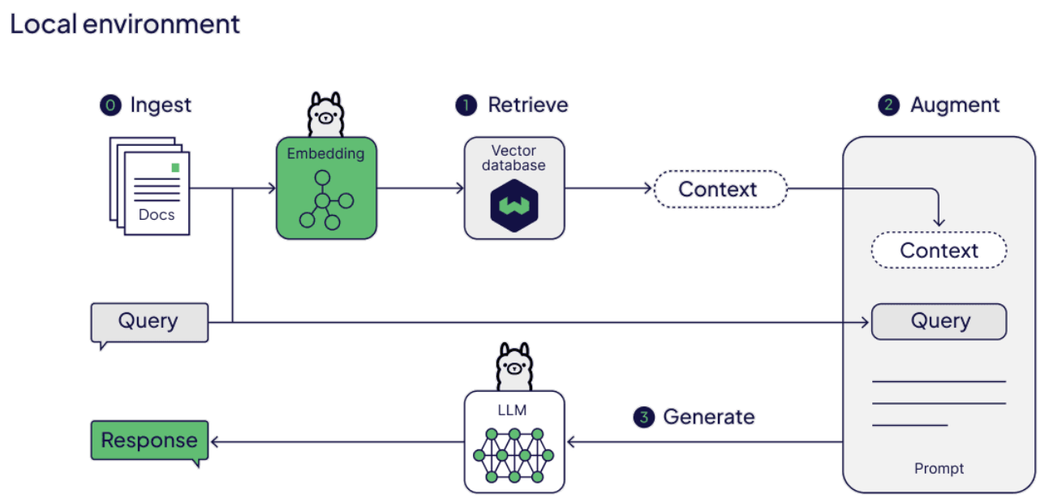


Fig.01 -
Source - Author (2025)

3.3.3 Generative Layouts

3.3.3.a Physics Simulation

Physics simulation treats architectural space planning as a constraint-satisfaction problem where rooms are modeled as dynamic particles or bubbles. By utilizing physics engines, most notably Kangaroo, a Live Physics plugin for Grasshopper, designers can simulate forces such as attraction, repulsion, and collision to find an optimal spatial equilibrium. The process begins by representing each room as a node or circle, with spring forces acting as desired adjacencies. If the planning logic dictates that two rooms must be adjacent, a strong attraction force is applied; conversely, collision goals prevent rooms from overlapping, and boundary goals keep them within the floor plate.

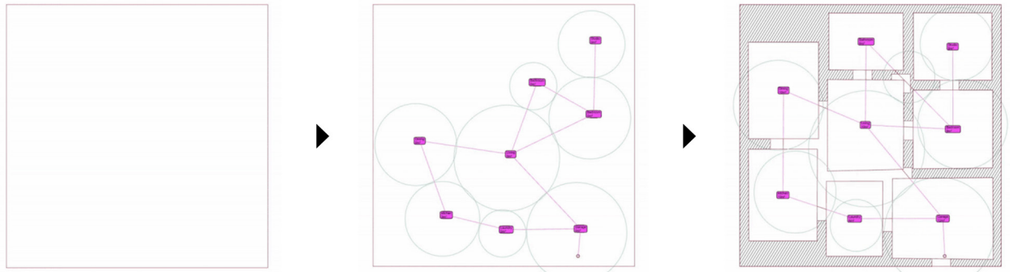
This approach is highly effective for residential typologies, where functional efficiency is paramount. For example, research into the Egyptian National Housing Project demonstrates how parametric modeling can be used to generate housing layouts that respond to specific socio-economic and functional requirements. By setting parametric constraints for room sizes and relationships, the system can automatically produce varied unit configurations that meet statutory standards while maximizing spatial utility (Mohamed Elsayed et al., 2018).

Similarly, the Bubble Dojo Casa House project by Miguel Baron illustrates the transition from a conceptual bubble diagram to a physical floor plan through force-directed simulation. In this workflow, the bubble diagram is not a static sketch but a live system. As the Kangaroo solver runs, it iteratively repositions the rooms until they satisfy the adjacency and area constraints, effectively form-finding the layout. This method allows the designer to visualize how competing requirements, such as the need for a large living area versus the requirement for bedroom privacy, physically resolve into a coherent geometric arrangement.

Relevance

The logic of physics simulation provides the primary spatial solver for the computational mediator developed in this research. While the Large Language Model (LLM) handles the high-level reasoning and identifies the necessary proximity relationships from the iHFG manuals, the physics engine acts as the mechanism that physically executes those relationships in the CAD environment. By integrating a physics-based solver like Kangaroo, the proposed workflow translates the textual must-be-near rules from the iHFG into physical attraction forces, ensuring that every spatial bubble maintains its mandatory size as defined in the Schedule of Accommodation (SOA).

This methodology allows for a dynamic and interactive design process where stakeholders can observe the layout self-organize in Rhino in response to their textual prompts. Because the physics engine operates in real-time, any update to the design brief instantly recalibrates the forces, providing immediate visual feedback on how clinical constraints impact the overall floor plan. This ensures that the final design is not just a static compliant box but a mathematically optimized configuration that reflects the complex, interdependent flows of a healthcare environment.



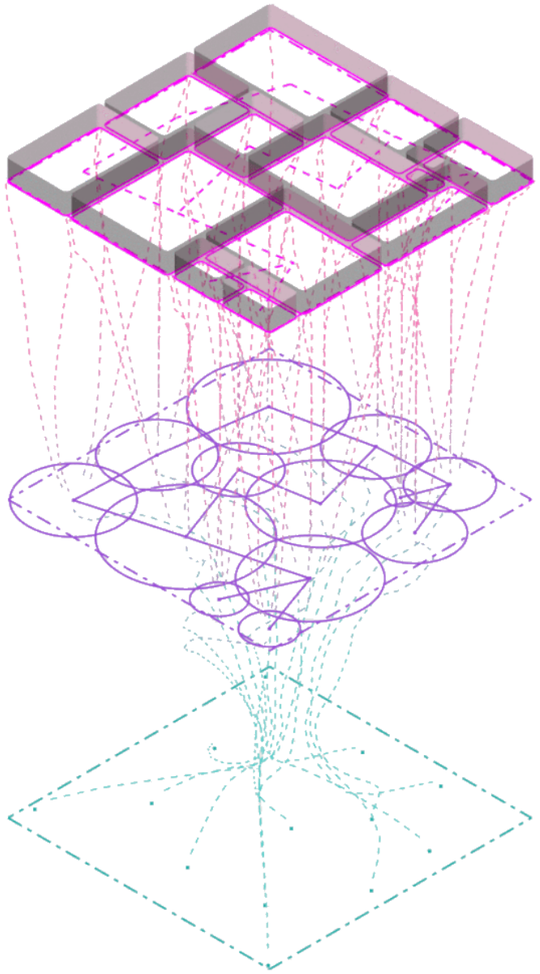


Fig.01 -
Source - Author (2025)

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

3.3.3.b Packing Algorithms

Packing algorithms offer a mathematical framework for Architectural Space Planning (ASP) by treating the layout process as a constrained geometric optimization problem. The core objective is to arrange a set of functional units within a defined boundary while maximizing space utilization and ensuring no overlaps occur. Unlike purely generative sketches, packing algorithms act as a formal placement engine that translates a list of required rooms into a mathematically valid physical arrangement.

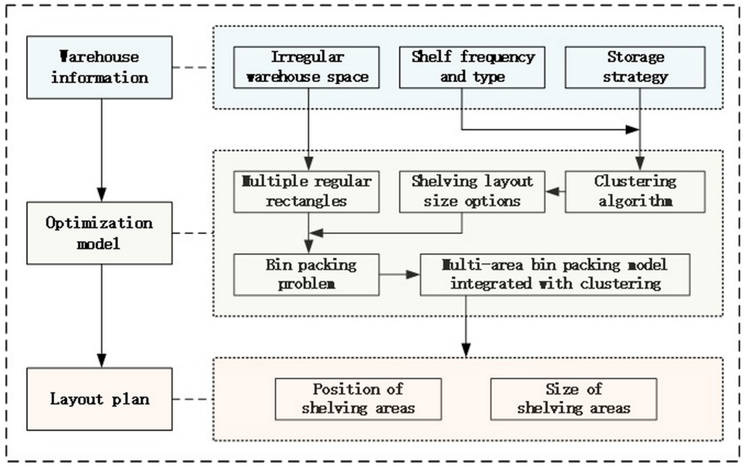
The methodology proposed by Zhang et al. (2024) addresses the complexities of irregular building boundaries by first transforming them into multiple regular rectangular sub-regions. The logic of this approach relies on a Class-Based Strategy, which categorizes functional units (such as specific types of clinical rooms) and clusters them into homogeneous rectangular areas. This is achieved by converting the traditionally non-linear clustering problem into a linear selection problem, allowing the system to choose from various pre-calculated regular layouts of different shapes and sizes.

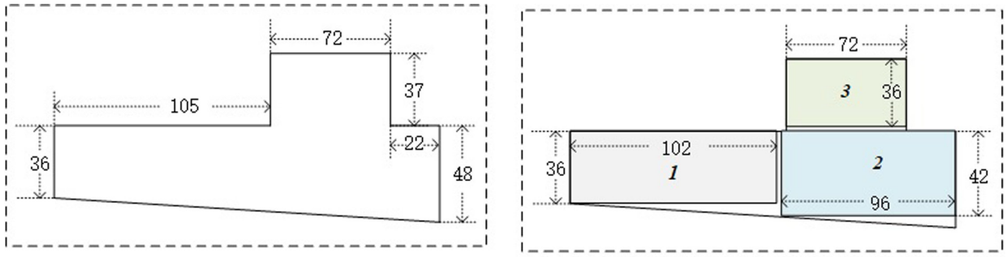
By integrating this clustering logic with a multi-bin size packing model, the system can solve complex spatial arrangements with significantly higher efficiency than standard two-dimensional bin packing methods, reducing the number of computational variables by over 80% and shortening solution times from hours to seconds (Zhang et al., 2024).

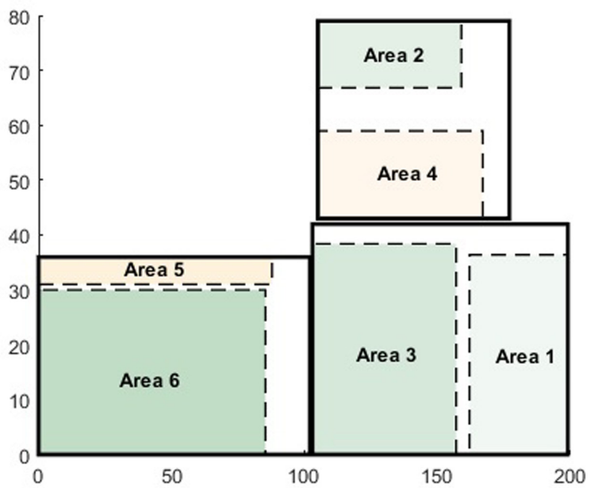
Relevance

The study of packing algorithms is a relevant area of research for understanding the technical means to achieve generative floor plans. It establishes a rigorous mathematical framework for handling irregular architectural boundaries, which are common in healthcare facility design. By examining how functional units can be clustered into classes, this area of study highlights a structured approach for maintaining complex operational adjacencies and technical requirements within a generated layout.

Analyzing these packing frameworks is essential for identifying how computational systems can transition from high-level clinical logic to optimized geometric configurations. This research area demonstrates that through the systematic application of clustering and optimization algorithms, it is possible to achieve a high degree of spatial efficiency and compliance. Understanding these precedents provides the foundational logic for developing automated tools that can physically execute the proximity and area standards defined in healthcare manuals within a CAD environment.







References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

Fig.01 -
Source - Author (2025)

3.3.3.c Agent-Based Simulations

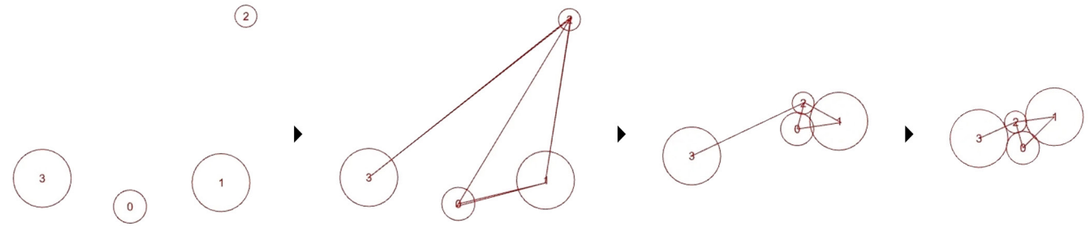
Agent-based simulation (ABS) treats architectural space planning as a dynamic system where individual functional units, or agents, interact to reach a spatial equilibrium. Unlike static drafting, this method utilizes an adjacency matrix as the primary input to define the necessary relationships between spaces. In frameworks like the Floating Bubble project, rooms are represented as autonomous bubbles connected by adjacency lines that act as virtual springs. The system solves for proximity, overlap, and size by applying iterative forces: attraction forces pull related rooms together, while repulsion forces prevent overlapping and maintain the required area for each unit. As the simulation progresses, these bubbles shift and resize until they satisfy the programmatic constraints, at which point the circular representations are converted into hard room geometry, such as polygons or rectangles.

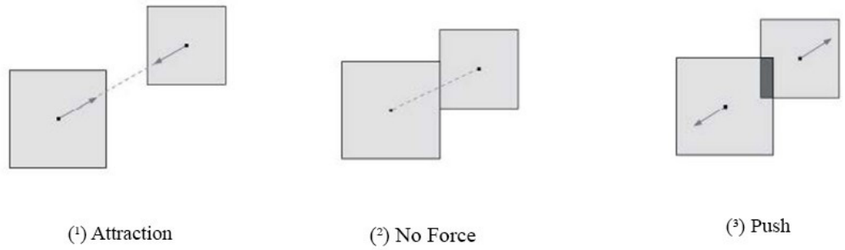
The logic behind these simulations is rooted in a bottom-up approach where the overall layout emerges from local interactions. As described by Lin and Hsu (2010), agent-based modeling allows for the exploration of non-linear spatial arrangements that traditional top-down methods might overlook. By assigning specific behaviors to each room, such as a desire to be near a window or a requirement to be adjacent to a corridor, the system can navigate complex trade-offs between competing design goals. This creates a flexible generative process where the input data (the adjacency matrix) directly dictates the emergent form, ensuring that the resulting layout is a functional manifestation of the initial design brief.

Relevance

The structural logic of agent-based simulations is fundamentally analogous to the architecture of Machine Learning (ML) graphs, particularly in the way they utilize the concept of nodes and edges. In this comparison, rooms are viewed as nodes embedded with specific features, such as area, equipment requirements, and clinical function, while the adjacency lines represent the edges that define the proximity chart. This relationship-driven structure is highly relevant because it mirrors how Graph Neural Networks (GNNs) process spatial information. By treating the layout as a graph of interconnected features, ML models can move beyond simple simulation to perform complex predictive analysis, determining the probability of a layout's success based on the integrity of its node-and-edge connections.

Machine learning models benefit significantly from this representation because it allows for the synthesis of complex floor plans through the evaluation of proximity weights. Instead of relying solely on iterative physical forces, a graph-based ML model can utilize the proximity chart to recognize patterns in high-performance layouts and apply those learned features to new design problems. This makes the agent-based logic a critical conceptual precursor to GNN-based layout generation, as it establishes how discrete architectural data can be structured into a network that is both spatially aware and mathematically auditable. For this study, the node-and-edge concept provides the necessary link between the qualitative clinical logic of the iHFG and the quantitative spatial evaluation required for automated compliance checking.





References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

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3.3.3.d Spatial Adjacency Simulations

While previous research directions primarily focus on 2D layout generation using polygons or circles, contemporary advancements have expanded into 3D generative design workflows. This shift moves beyond the flat plane to address the volumetric complexity of architectural space, where rooms are treated as 3D shapes or voxels within a three-dimensional coordinate system. According to the research presented in the CDRF 2022 proceedings (Yuan et al., 2023), 3D spatial adjacency simulations utilize a hybrid intelligence framework to solve for complex programmatic relationships across multiple levels and volumes.

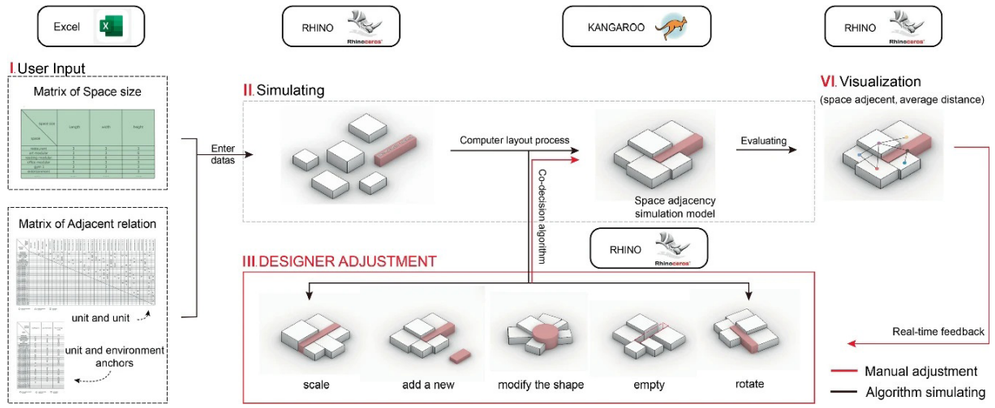
The methodology relies on representing spatial requirements as a 3D adjacency network. In this workflow, the machine does not simply arrange 2D shapes; it evaluates the proximity and connectivity of 3D volumes. The process utilizes a Human-Machine Collaborative Workflow where the human designer defines the high-level intent, such as vertical adjacencies (stacking), light requirements, and core connections, while the computational system performs the heavy lifting of solving the geometric packing and connectivity constraints in 3D space. This allows for the generation of complex architectural massing where internal spatial logic is resolved simultaneously with the external building form.

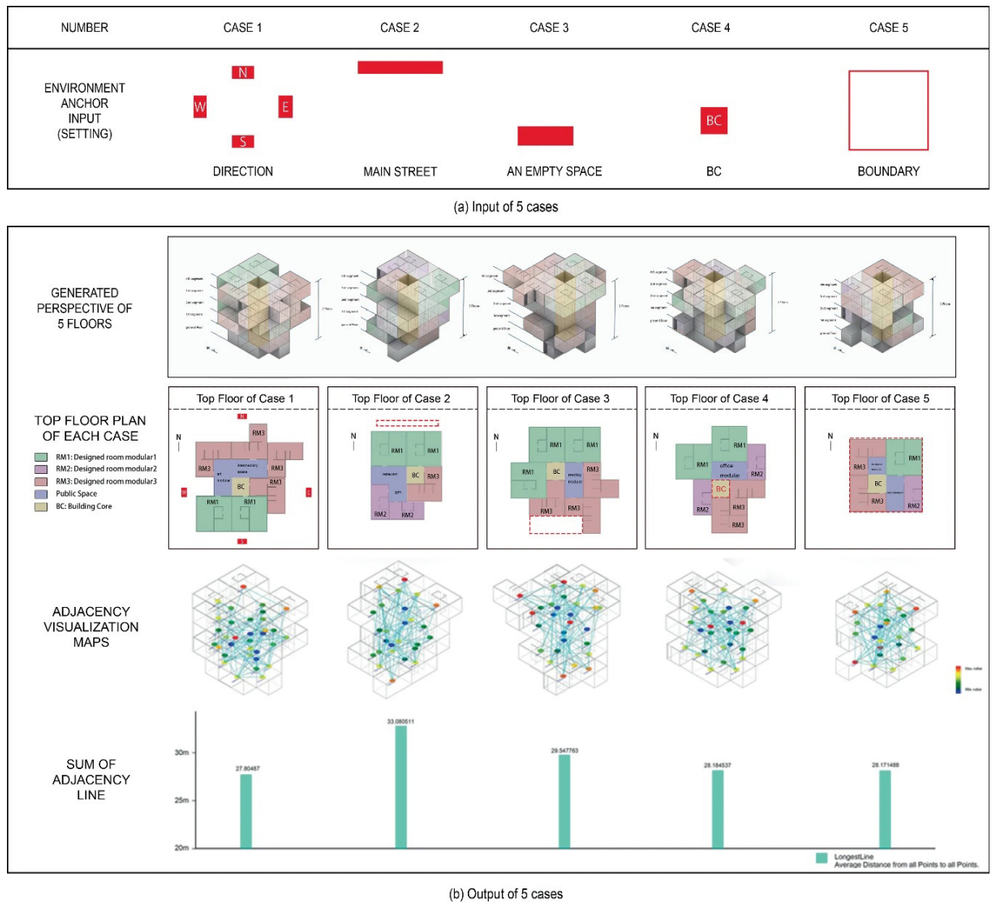
By operating in 3D, the simulation can account for factors that 2D layouts often overlook, such as vertical clinical flows, double-height spaces, and the impact of structural grids on spatial volume. The algorithm uses force-directed logic, similar to agent-based models, but applied to 3D vectors, ensuring that volumes attract or repel one another until they reach an equilibrium that satisfies the functional brief. This results in a generative output that is not just a plan, but a fully realized spatial block model ready for further architectural refinement.

Relevance

The transition to 3D spatial adjacency is critical for understanding how generative tools can move from simple departmental blocking to multi-story healthcare facility planning. In a hospital environment, clinical efficiency is often defined by vertical relationships, such as the proximity of Emergency Departments to upper-floor Operating Theatres via dedicated trauma lifts. By studying these 3D methodologies, this research identifies the technical means to evaluate and generate layouts that are vertically integrated, ensuring that the Logic Layer of the iHFG is maintained across the entire 3D volume of the building.

Furthermore, the emphasis on a human-machine collaborative workflow mirrors the objective of the proposed computational mediator. It highlights a future where the healthcare planner provides the 3D functional logic (the nodes and edges), and the machine provides the 3D spatial resolution (the voxels and massing). This ensures that even in complex, multi-level facilities, the design remains grounded in the rigorous technical standards of healthcare planning while allowing for the architectural flexibility offered by 3D generative design.





References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

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Source - Author (2025)

3.3.4 Machine Learning for Architectural Layouts

3.3.4.a A Review of ML Graphs

Graph technologies store, query, process, analyse, and visualise data as networks of interconnected entities, similar to how the human brain works. (Graphaware.com, 2026)

The fundamental structure of a graph in machine learning is defined by its ability to represent not only individual data points but also the intrinsic relationships between them. At its simplest level, a graph is composed of nodes, which represent entities, and edges, which represent the connections or interactions between those entities. This multi-layered data structure allows computers to move beyond isolated data analysis and instead reason about the topology, or shape, of a network (David Mack, Medium, 2018).

Unlike traditional tabular data, graphs excel at modeling systems where connectivity defines the identity of the constituents. According to foundational GraphML principles, the primary components include:

Nodes: Representing discrete entities, such as individual rooms or zones in a hospital.

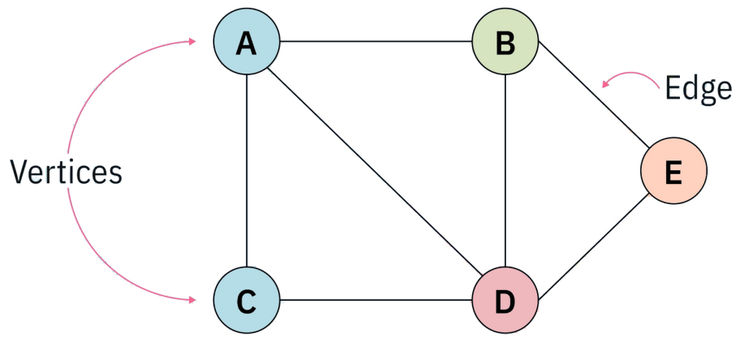
Edges: Representing relationships, such as physical adjacencies, circulation paths, or sterile barriers.

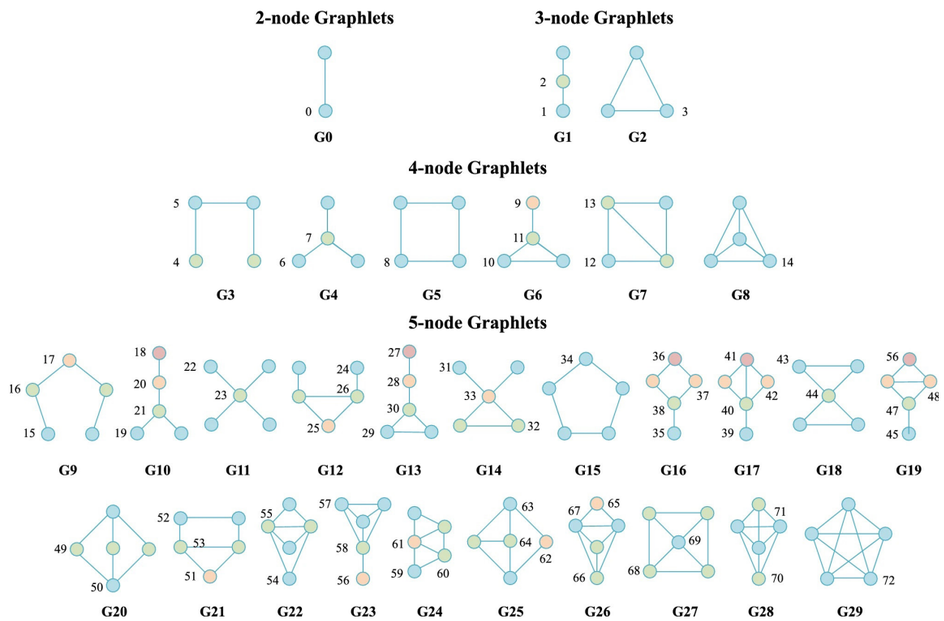
Features: Key-value pairs attached to nodes or edges that store metadata, such as a room's area, clinical function, or specific equipment requirements.

To process this information, graphs are mathematically represented in two primary ways: adjacency matrices and adjacency lists. An adjacency matrix is a square grid that records every possible connection in the network, which is highly efficient for dense graphs where most entities are related. In contrast, an adjacency list is a more memory-efficient format for sparse graphs, where most entities are only connected to a few others, a condition common in architectural floor plans. Querying these structures involves using specialised languages, such as Cypher or AQL, to perform traversals. These traversals enable a system to navigate from one node to another, allowing it to find patterns, including identifying the shortest path between two points or finding clusters of highly interconnected entities (Clémentine Fourrier, Hugging Face, 2023).

To manage this complex data, specialized Graph Databases are used. Neo4j is the industry leader for property graphs, utilizing the Cypher query language, which is designed for intuitive pattern matching (e.g., Find all nodes connected to X). ArangoDB is another popular multi-model database that uses AQL, a declarative language that allows for high-performance traversals across interconnected datasets. These tools are widely used in non-architectural fields for fraud detection, recommendation engines, and social network analysis, where identifying hidden patterns in large networks is critical.

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)





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3.3.4.b Graph Types

Machine learning graphs are categorized by how they structure information and the type of reasoning they enable. In architectural design, specific categories are used to transition from abstract rules to physical geometry:

Knowledge Graphs (KGs)
These are semantic networks that combine graph databases with a formal ontology to represent facts and clinical logic. A KG can encode that an Operating Theatre requires Positive Pressure, linking a room node to a technical requirement. These are causal and interpretable, allowing a system to explain why a specific adjacency is mandatory based on standards like the iHFG (Google Research, 2021).

Spatial Graphs
These represent the physical topology of a building. Nodes correspond to spatial elements (rooms or voxels), and edges represent physical boundaries or adjacencies. Unlike image-based representations, spatial graphs maintain relational links, allowing an ML model to reason about flow and connectivity without being restricted to a fixed pixel grid.

Property Graphs
This is the primary technical implementation where every node and edge can contain a detailed list of attributes (e.g., Area: 25sqm, ID: 402). This makes the graph a rich, queryable database where designers can identify clinical rooms that lack necessary sterile connections through pattern matching.

3.3.4.c Graph Descriptions

The mathematical behaviour of a graph is determined by how its edges are defined, which dictates the flow of information and the hierarchy of relationships within the network. These descriptions are essential for accurately modelling the physical and operational constraints of a built environment (Hugging Face, 2023).

Directed vs Undirected Graph
In an Undirected Graph, edges represent a mutual, symmetric relationship with no specific orientation; if Room A is adjacent to Room B, Room B is inherently adjacent to Room A. In contrast, a Directed Graph (or Digraph) uses edges with a specific direction to indicate a one-way relationship or a sequential dependency. This is crucial for modeling processes where the order of movement matters, such as a patient's journey through a clinical department or the flow of mechanical systems from a source to a terminal (Octavian, 2018).

Weighted vs Unweighted Graph
An Unweighted Graph treats all connections as equal, focusing purely on whether a relationship exists (binary). A Weighted Graph assigns a numerical value (weight) to each edge to represent the strength, cost, or importance of that connection. These weights allow a model to prioritize certain relationships over others, such as a high-priority adjacency between a resuscitation bay and an imaging suite versus a low-priority connection between an office and a staff lounge (Google Research, 2021).

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

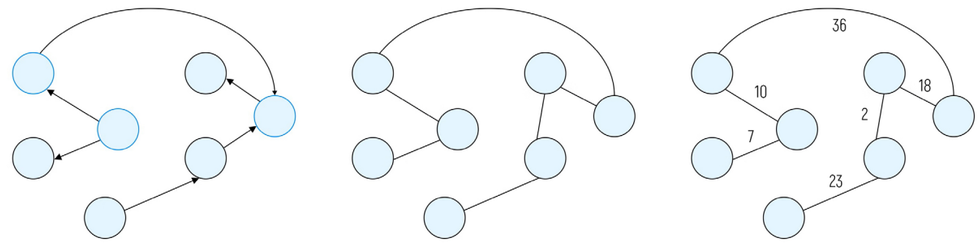
3.3.4.d Graph Prediction Classes

Machine learning on graphs is categorized into three primary functional levels, each defining the scope of the prediction task. These classes allow models to reason at different scales, from individual components to the entire system, making them essential for handling the tiered complexity of architectural data (Hugging Face, 2023; Google Research, 2021).

Node-level Tasks
These involve predicting a property or category for individual nodes. In a graph, a node's identity is defined by both its own attributes and the characteristics of its immediate neighbors. Common tasks include Node Classification, where the model determines the type of an entity, and Node Regression, where it predicts a continuous value like a coordinate or area (Octavian, 2018).

Edge-level Tasks
These focus on the relationships between nodes. The primary task is Link Prediction, which determines the probability that an edge should exist between two nodes. This is used to identify missing connections or to suggest new interactions based on the existing network topology (Hugging Face, 2023).

Graph-level Tasks
These evaluate the entire graph structure as a single entity. The model performs Graph Classification or Graph Regression to predict a global property, such as the overall efficiency, cost, or compliance of a complete network.



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3.3.4.e Graph Neural Networks (GNNs)

Graph Neural Networks (GNNs) are a class of deep learning models specifically designed to operate on graph-structured data. While traditional neural networks, such as CNNs for images or RNNs for text, are optimized for regular, grid-like or sequential data, GNNs are built to handle the irregular connectivity found in real-world systems like molecules, social networks, and architectural floor plans. By extracting features from both the individual entities (nodes) and the relationships between them (edges), GNNs can perform relational reasoning, making predictions that consider an entity's specific neighborhood context rather than treating it in isolation (Distill, 2021 & MathWorks, 2025).

The fundamental architecture of a GNN follows a **Graph-In, Graph-Out** paradigm. The model takes an initial graph as input and progressively transforms the information within it without altering the underlying connectivity. To function, a GNN requires two primary types of input data:

Structural Information: Typically represented as an Adjacency Matrix, which defines how nodes are connected.

Feature Information: Multidimensional vectors or embeddings assigned to Nodes (e.g., room size, type), Edges (e.g., door width, distance), and a Global Context (e.g., total building area, site orientation).

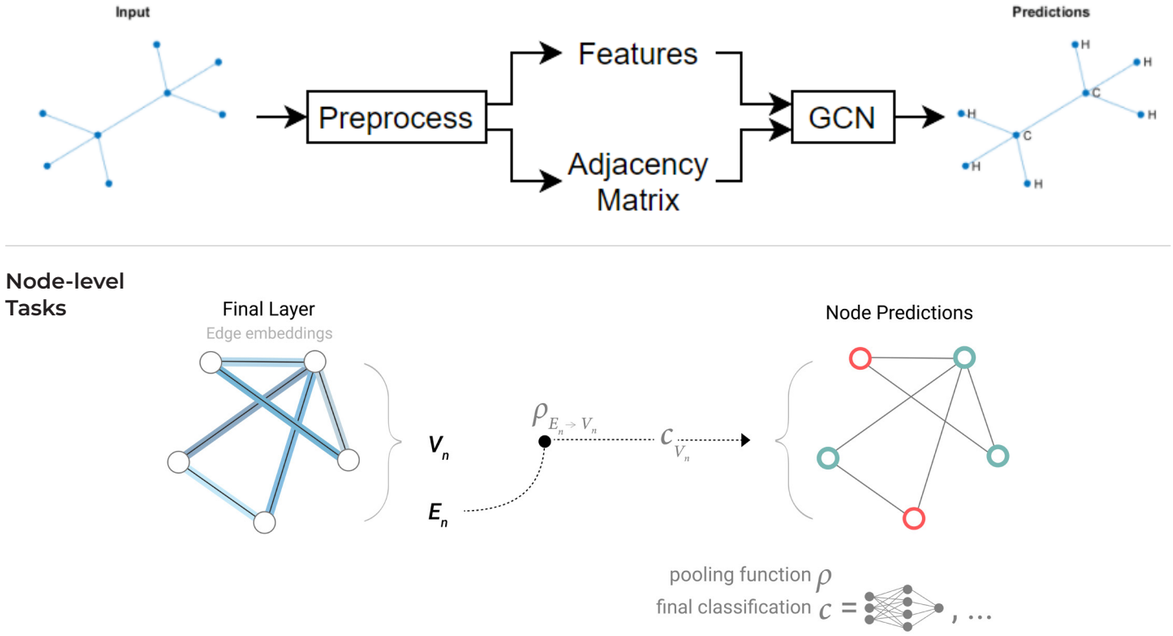
The core mechanism of a GNN is message passing. In each layer, every node gathers information from its immediate neighbors (Aggregation), combines it with its own data, and computes a new embedding or representation (Update). As information passes through multiple layers, a node can eventually learn about parts of the graph that are several hops away.

The final output of the GNN is a set of updated embeddings that can be used for the three primary prediction classes: Node-level (e.g., classifying a room), Edge-level (e.g., predicting a missing connection), or Graph-level (e.g., assessing the entire layout's efficiency) (Distill, 2021 & MathWorks, 2025).

Relevance

The direct parallel between graphs and architectural planning allows a floor plan to be treated as a Spatially-Attributed Graph. In this framework, rooms (represented as polygons) are mapped as Nodes, while the functional adjacencies between them are mapped as Edges. This abstraction is highly effective for healthcare planning because it allows the computational mediator to read and write room features, such as clinical type, mandatory area (Sq. M.), based on the iHFG SOA.

By representing a department as a graph, the machine can evaluate these adjacencies and check for program requirements against the standards defined in the iHFG. Furthermore, by identifying the features of each node, the ML model can predict the optimal placement of rooms within a given department outline based on the density of their connections. This graph-based representation provides a common language for both the human planner and the machine, ensuring that the clinical logic is mathematically sound before a single wall is drawn in the 3D environment.



References - [(iHFG Part B, 2025)](), [(Health Facility Guidelines, Website, 2026)]()

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3.3.5 Graphs & Architectural Layouts

3.3.5.a Extracting Graphs from Layouts

The conversion of architectural floor plans from raster images into mathematical graphs is a fundamental task in automated design analysis. Historically, this process was dominated by rule-based methods, such as the Hough transform for wall detection or sub-pixel edge detection, which often struggled with the high variability of architectural notation and noise in legacy scans. Modern methodologies have shifted toward learning-based approaches, where Computer Vision (CV) and Graph Convolutional Networks (GCNs) are combined to recognize both the geometry and the underlying topology of a space. This transition allows for the extraction of a Layout Graph, a structured representation where rooms are nodes and adjacencies are edges, preserving the functional logic of a plan independently of its visual style (Pizarro et al., 2022).

The technical pipeline for extracting these graphs follows a structured sequence that moves from pixel-level classification to topological induction:

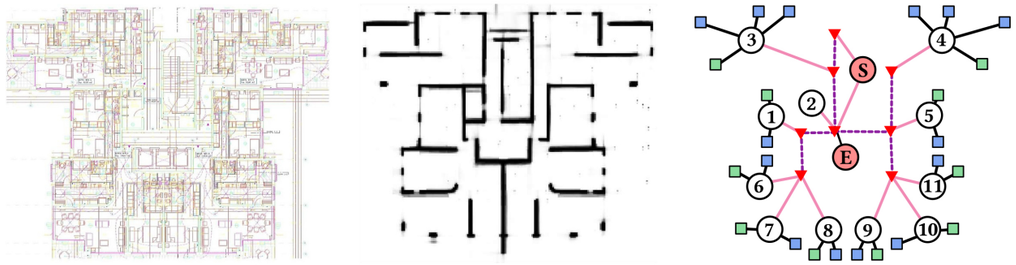
Semantic Segmentation & Multi-Task Learning
The initial stage utilizes Convolutional Neural Networks (CNNs) to classify pixels into semantic categories such as walls, doors, windows, and room types. Advanced frameworks, such as the one proposed by Knechtel et al. (2024), employ a multi-task network that performs boundary detection and room labeling simultaneously. This ensures that the structural skeleton of the building is recognized in tandem with its functional zones.

Long-Range Dependency Capture (SCG)
A significant challenge in raster analysis is the local nature of CNNs, which may struggle to connect distant but related elements (e.g., two ends of a long corridor). To solve this, Self-Constructing Graph (SCG) modules are used to automatically induce a graph from the latent features of the image. This allows the system to capture long-range dependencies and functional relationships before the final vectorization takes place (Knechtel et al., 2024).

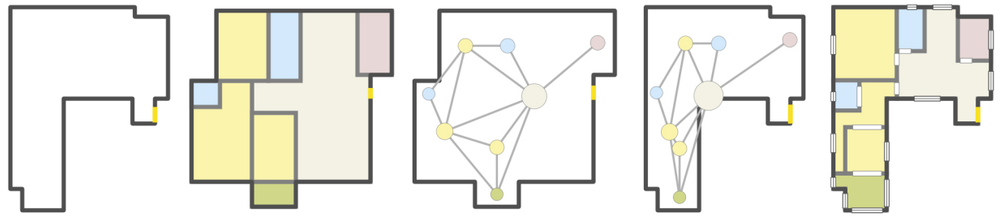
Structural Vectorization
Once the semantic layers are isolated, the raster data is converted into geometric primitives. This involves identifying wall junctions and endpoints to form closed polygons. Each polygon represents a discrete room unit.

Topological Graph Induction
The final step translates the vectorized polygons into a relational graph. As detailed in the Graph2Plan framework (Hu et al., 2020), room centroids are extracted as nodes, while edges are generated based on shared boundaries or door connections. These nodes are then embedded with features derived from the semantic labels, such as room type, area, and clinical requirements.

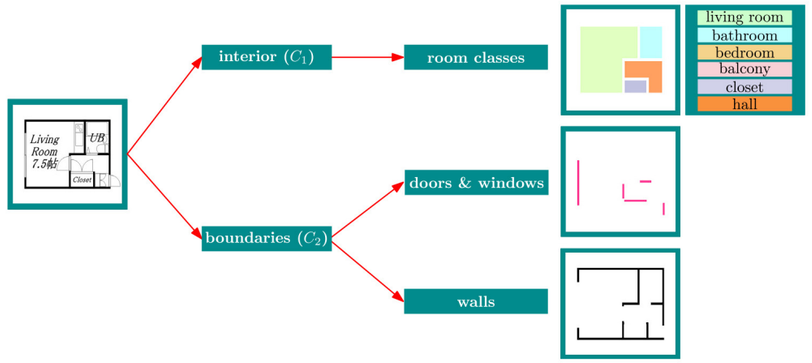
References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)



(a) Rasterized floor plan. (b) Segmented walls. (c) Graph model.



(a) Input boundary (b) Retrieved floorplan (c) Retrieved graph (d) Adjusted graph (e) Final floorplan



Relevance

The ability to extract graphs from raster plans is technically vital for capturing the clinical adjacencies found in the iHFG (International Health Facility Guidelines). Most medical standards are currently trapped in static PDF diagrams. By applying this extraction pipeline, the research can systematically translate these standard layouts into a machine-readable Logic Layer.

Furthermore, this methodology enables the creation of a surrogate training dataset. Since healthcare-specific layout datasets are significantly rarer than residential ones (such as RPLAN), extracting graphs from the thousands of standardized layouts in the iHFG provides the foundation for training GNN-based generative models. These extracted graphs serve as the ground truth for the computational mediator, allowing it to generate complex department layouts on new floor outlines that are guaranteed to follow the topological rules and clinical flows established by global healthcare standards.

Fig.01 -
Source - Author (2025)

3.3.5.b Extracting Layouts from Graphs

The reverse process of layout analysis is Layout Synthesis, which involves translating a mathematical graph back into a vectorized floor plan. In this workflow, the graph serves as the architectural DNA, carrying the programmatic requirements and clinical logic that a system must physically manifest within a defined boundary. This technical transition bridges the abstract functional requirements (program) with concrete spatial geometry.

Recent research identifies this synthesis as a critical step in automated design, where the graph acts as a constrained blueprint. According to the Graph2Plan framework, this allows for a user-in-the-loop design where topological constraints are satisfied before the geometric layout is generated (Hu et al., 2020). By treating the architectural problem as a graph-to-layout task, the system ensures that the resulting design is not just a collection of rooms, but a functional network that preserves the intended operational flow (van Engelenburg et al., 2025).

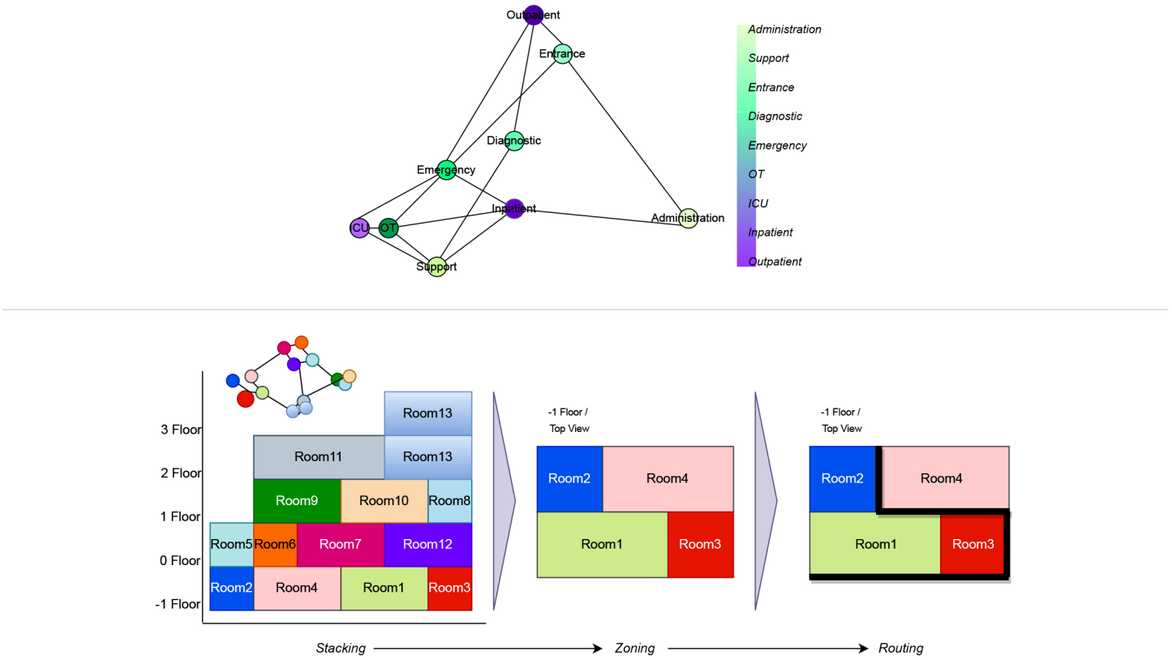
The conversion of a layout graph into a vector plan utilizes deep learning architectures, such as Graph Neural Networks (GNNs) or Graph Transformers, to process relational data into spatial coordinates. The pipeline typically follows three technical stages:

Relational Embedding (Input)
The input consists of Nodes (rooms) and Edges (adjacencies). Each node is embedded with Features derived from the design brief, such as room type and required area. The GNN processes these nodes through message passing, where each room learns its optimal position based on the features of its neighbors (Tang et al., 2024).

Geometry Prediction (The Solver)
The model predicts the geometric properties for each node. This includes the Centroid (x, y coordinates) and the Bounding Box (width and height). As noted in the MSD Benchmark study, modern architectures like Graph Transformer GANs are used to ensure these predicted boxes are non-overlapping and respect the building boundary (van Engelenburg et al., 2025).

Vector Refinement (Output)
The predicted boxes are refined into clean, vectorized polygons. This stage ensures that walls are aligned and the geometry matches the user-provided building footprint.

This computational process is a digital evolution of traditional architectural tools. The Nodes and Edges of the graph function similarly to a Bubble Diagram, where rooms are bubbles and adjacencies are the spring forces pulling them together. Furthermore, the graph is a direct manifestation of a Proximity Matrix. While architects traditionally use these matrices to manually map relationships, the GNN uses the matrix as a structured mathematical input to automate the spatial solving process (Jia, 2025; Çubukçuoğlu, 2023).



Relevance

The ability to extract layouts from graphs provides a feasible workflow for integrating the Schedule of Accommodation (SOA) and the Functional Relationship Diagrams found in the iHFG guidelines. By encoding the SOA as node features and the relationship diagrams as edges, the computational mediator can synthesize layouts that are inherently compliant with global healthcare standards.

This framework allows for a scalable design process that works at both the Micro (departmental) and Macro (floor-plate) levels. A user can input a custom building polygon, and the system can write a complex clinical layout into that specific shape by following the topological rules established by the iHFG. Furthermore, this approach is future-proof; as healthcare guidelines evolve or new clinical adjacencies are introduced, the architect only needs to update the input graph, allowing the generative process to adapt without a total system redesign.

References -
(iHFG Part B, 2025), (Health Facility Guidelines, Website, 2026)

Fig.01 -
Source - Author (2025)

04.
PROJECT PLANNING

4.1 Methodology

1. Parametric Generation and Base Data Creation
(Rule-Based Floor Plan Generation / Parametric Optioneering)
This stage focuses on Rule-Based Floor Plan Generation using a Parametric Optioneering approach. The process begins by developing initial zoning layouts governed by spatial, proximity, and volumetric parameters derived from the project brief. This computational approach will automatically generate the base planning grid and room geometry, while also serving a dual purpose: to create a foundational, structured dataset essential for training subsequent Machine Learning (ML) models.

2. Design Compliance Validation Model
(Validation Model for Compliance Checking against Design Standards & Project Brief)
A Pre-Trained Text Interpreter Model will be utilized to convert unstructured data from client Request for Proposals (RFPs) and design briefs into a structured format. This structured data will define the core design parameters and functional requirements. The resulting model will then function as a Real-Time Validation Engine, verifying the generated layouts for compliance against both the input project documents and mandated local or international design standards.

3. AI-Driven Spatial Error Detection and Correction
(Detecting Errors using Graph Representation of Room Boundary/Geometry)
A Custom Machine Learning Model will be developed to analyze the spatial configuration using a Graph Representation of Geometry. This model will be inherently spatially aware, understanding room boundaries, proximities, and topological relationships. Based on the input design standards and program datasets, it will automatically detect design errors or critical shortcomings. A key extension of this stage will be the development of an Automated Correction Function to suggest and implement fixes for identified violations.

4. Model-Context Protocol (MCP) for Collaborative Modification
(MCP-Based Layout Modifications through Textual User Inputs)
To enhance collaboration between internal design teams and external healthcare experts, a unique web-based front-end interface (a Dashboard) will be developed. This interface will employ a Model-Context Protocol (MCP), providing direct, constrained access to the layout model. Users can submit textual comments or feedback, which the system interprets to suggest layout alterations. These modifications are strictly constrained by the parametric model and are concurrently verified for compliance by the validation engine, ensuring that the designer retains the ultimate decision-making author

4.2 Timeline Overview

Phase 1 - Datasets & Graphs
4 Weeks - 28th January to 24th February

Dataset Preparation for Model Training
- GH Parametric Surrogate Model
- Synthetic Dataset based on iHFG Standards (Backup)

LLM RAG Integration for iHFG Standards
Knowledge Graphs on
Graph Network for Department Zoning (Limited Features)

Phase 2 - Fine-Tuning, Validation & Geometry
6 Weeks - 25th February to 7th March

Fine-tuning LLM RAG for Area Statement Automation (Testing GraphRAG)
- Dataset Fine-tuning & Feature Correction for GNN

Testing on Toy-Dataset (Backup)
- Defining Validation Parameters
- Verifying Graph Accuracy

Quantitative Analysis against iHFG Standards
Graph to Geometry Pipeline (Initialization)

Phase 3 - Prototype Workflow & Dashboard
6 Weeks - 8th March to 19th May

Pipeline Prototype (Demo)
- Program Brief & Area Statement Generation
- Generative Floor Plan (using Graphs)

Frontend Dashboard for User Interaction
- LLM Interface (Text Interaction with Design Option)
- Geometry Live Preview (Rhino.Compute)
- Real-time Feedback & Validation

Curriculum Vitae

S U M M A R Y

Dedicated and innovative Architect & Design Technologist with 5 years of experience in the AEC industry. Demonstrated expertise in design concepts, computation & automation across diverse building typologies. Proficient in leveraging cutting-edge technologies to drive sustainability initiatives and streamline design processes and proven ability to integrate technology seamlessly into the design workflow, enhancing efficiency and fostering environmentally conscious solutions. A results-driven professional with a passion for creating impactful, sustainable, and data-driven designs. Committed to staying at the forefront of industry trends and emerging technologies.

E D U C A T I O N

MASTER'S PROGRAM
CURRENT

***Technische Universiteit Delft, The Netherlands** (TU Delft)*
MSc Architecture, Urbanism & Building Science - Building Technology Track (Specialisation)
Completed Courses - Computational Intelligence (Develop AI & ML Applications), Design Informatics (Robotics & Digital Fabrication), Technoledge Facade Design, MEGA (Collaborative Large Scale Design Project - Computational Designer Role - Best Computational Project)

BACHELOR'S PROGRAM
2014-2019

***Anna University, Chennai, India** (McGan's Ooty School of Architecture)*
CGPA - 7.78 (3.3 GPA) - First Class Degree - Council of Architects Registered - CA/2019/113651
Thesis - Research Centre & Simulation Facility for Martian Environment
6x Design Studio, Urban Survey & Design - Kancheepuram City, Climate & Built Environments, Mechanics of Structures, Environmental Science, Construction Technology, Design Competitions

W O R K E X P E R I E N C E

DESIGN TECHNOLOGIST
04/2023-08/2024

Edifice Consultants, Mumbai, India
Think Tank Vertical Spcializing in Develping Design Automation Tools, Managing Data between Teams & Softwares, and, Implementing Workflow Pipelines.
Key role in testing, developing, depolying & training on various technologies that make the design process streamlined.

- *Sustainability Study & Topography Analysis Tools for Designers*
  Took lead role and responsibility in creating custom Grasshopper Clusters that take advantage of the various climate plug-ins like Ladybug & Honeybee. Similarly, created components for Topography Modeling, Analysis & Water Simulations. These tools & reference manuals were helpful for designers during early stages of design.
- *Custom Modular Designed Hospitals for a Confidential Client*
  Developed an automation script to develop the facade & architecture model for a given linear curve input, assembled using a kit-of-parts concept, in order to be repeated across various locations using the same construction materials, details & techniques.
- *Software Interoperability between Rhino & Revit (Design Documentation)*
  Assisted various projects on data interchange for complex facade modules/panels to Revit for obtaining constuction drawings using Rhino.Inside & Speckle for Rhino, played a major role in simplifying facade modules for fast documentation and easier fabrication.
- *"EDI-Cation" - Hands-on Software Training & Educational Content Production*
  Self-initiated company wide training on Rhino & Grasshopper to architects and engineers, enabling designers to develop complex geometries with accuracy, perform climatic analysis & simulations, and futher help smoothly transition to documentation stage.

DESIGN ARCHITECT
12/2019-03/2023

Edifice Consultants, Mumbai, India
Think Tank Vertical Spcializing in Design Concepts for Large Healthcare, Educational, Hospitality, Corporate Architecture, and, Civic & Cultural Spaces.
Was successful in running a small team of designers, key in delivering fast paced concept & schematic stage projects, involving a high level of creativity, speed, accuracy & consistency, with a major focus on design ideation, narration, design development and a data & tech-driven process.

CIVIC, PUBLIC & CULTURAL

- *TCS Phase-2 Master Plan & Architecture, Noida, India* (Corporate Architecture)
- *Phoenix Group Commercial Development, Mumbai, India* (Corporate Architecture)
- *SAP Software Campus Architecture, Banglore, India* (Corporate Architecture)

CORPORATE CAMPUS

- *Adaptive Re-Use Power Museum for Bihar State Power Holdings, Patna, India* (Civic)
- *San Januario International Stadium for Club de Regetas, Rio de Janeiro , Brazil* (Civic)
- *Kharghar Centre of Excellence for Football, Navi Mumbai, India* (Civic)
- *Mata Amrita Heritage & Cultural Complex, Mahabalipuram, India* (Civic)

EDUCATIONAL SPACES

- *Netaji Subhash Chandra Bose University of Excellence, Sikkim, India* (Educational)
- *Sharda University Film & Entertainment College, Delhi, India* (Educational)
- *Mahindra University School of Excellence, Hyderabad, India* (Educational)
- *Puneri Paltan Kabaddi Training Academy, Mumbai, India* (Educational)

HOSPITALITY PROJECTS

- *Private Home-Office for CEO of Reputed Private Hospital, Mumbai, India* (Hospitality)
- *SIBIN Group Mixed-Use Resort & Business Centre, Sikkim, India* (Hospitality)

HEALTHCARE FACILITIES

- *Sant Nirankari Mission - 1200-Bed Multi-Speciality Hospital, Delhi, India* (Healthcare)
- *TIL Private Mixed-Use Medi-City Master Plan, Gurugaon, India* (Healthcare)
- *AIG Group of Hospitals Expansion Master Plan, Hyderabad, India* (Healthcare)
- *Peerless Cancer Care & Research Centre, Kolkata, India* (Healthcare)
- *Mizoram State Cancer Institute, Aizawl, India* (Healthcare)
- *JSW CSR Mother & Child Care Hospital, Ballary, India* (Healthcare)
- *Karkinos Group of Cancer Hospitals, Multiple Locations, India* (Healthcare)
- *Jamia Hamdard Cancer Care Hospital & Research Centre, Delhi, India* (Healthcare)
- *Techno Global Group of Cancer Hospitals, Kolkata, India* (Healthcare)

RESIDENTIAL & DEVELOPER

- *Forum Row Housing Master Plan & Residential Design, Rajarhat, India* (Residential)
- *Smart World High-Density High-Rise Residential Master Plan, Delhi, India* (Residential)

DESIGN INTERNSHIP
2017-2018

BlueCube Inc., Chennai, India
Studio Specialising in Private Residences, Restaurants, Posh-Boutiques, Container Spaces, working with Reputed Clients from all over the state of Tamil Nadu.
Was part of the core design team, working on early stage designs for plotted developments, apartments and interiors for banquet halls, resto-bars and boutiques (concept & design documentation). Learnt about codal implications, client & vendor coordination, and, execution.

I N D U S T R Y C O U R S E S

2022 — ***Archi-Tech Network - Grasshopper 101, 102, 103 by Oliver Thomas***
An online learning platform for architects to learn digital tools, learnt to deal with data trees, and created a building generator script, the masterclass was helpful to course-correct workflow.

2020 — ***Meal.Design Live Academy - Rhino.Inside by Oliver Thomas***
An interoperability course covering the basics of translating geometry from Rhino to Revit using Rhino.Inside plugin for Grasshopper, making design & documentation seamless.

2019 — ***Autodesk Revit Architecture Training & Certification Course***
To complete the cycle from Concept to Design Documentation, underwent detailed training to work in Revit as a modeling, documentation & collaborative tool.

2018 — ***Rhino & Grasshopper Basics Tutoring at RVS School of Architecture***
Conducted one-day introductory training to 1st and 2nd year students of architecture, to understand the possibilities with Rhino & Grasshopper as a design tool.

Flux.Real Design Collective - Interplay of Mediums - NASA Convention
Assisted to help conduct a 2-day workshop on Experiential & Generative Experiements in Architecture, that enable users to visualize conceptual spaces in a cloud-VR environment.

2017 — ***Design Morphine - Generative Morphologies v4***
Underwent a rigorous 8-Day workshop on utilising the power of Rhino, Grasshopper & ZBrush to develop complex forms, culminating with a design option presentation & a 3D printed module.

Responsive Environments - Shridhar Mamidalaa from SDL
A 2-Day workshop introductory workshop on the use of Processing, Arduino & Robotics in Architecture, learnt the logic behind the setup and application of such tools and hardware.

Digital Intuition - Hyper_Interax - ZoNASA Convention
Introduction to digital fabrication and creating vivid interactive architectural systems, creating parametric designs using Firefly plug-in, a group activitiy included crafting an interactive model.

C R E A T I V E P U R S U I T S

ACTIVATE COIMBATORE 2021

Impact of COVID-19 on Urban Public Spaces - A Change in Function
A design exercise to create a change of selective places of interest and high footfall within the city limits of Coimbatore; spaces that are not of use or are currently under utilized. This project hopes to develop ideas that make the spaces more interactive and usable.

VECTOR -THERU KANCHEEPURAM 2019

Graphical Documentation of an Indian Streetscape - Capturing Culture & Emotions
Vector-Theru ("Vector" being the Graphic Format, unlimited lossless zoom + "Theru" being the Tamil for Street); Consisting of 17 different buildings and each having a different look & feel, capturing the essence and emotion of an Indian Streetscape.

ARCHITECTURAL BLUES 2017

Urban Photographic Documentation of Chennai's Iconic Historic & Modern Buildings
A selective collection of some of the most distinct, important and stunning architecture in various parts and localities of Chennai, Tamil Nadu, India. Inspired by "Architectural Blues" of China by photographer Kris Provoost.

C O M P E T I T I O N S

VOLZERO TINY LIBRARY 2023

Volzero Competition Participation
The brief for a rural library that engaged the local people and was to act as a space for knowledge sharing, learning & skill development. The proposed design goes a step further to create a sustainable unit, that follows local construction techniques and was contextually apt.

VOLZERO UNBOX 2018

Volzero Competition Participation
Participants were to design a public space in an urban or rural area using 4 container units. The design envisioned the creation of a culture-hub in a popular tourist location in Chennai; a place that is well connected by road & water, one that will pull people from various walks of life.

ISOLA LANSCAPE TROPHY 2017

NASA India - Design Competition Partcipation
The problem calls for a deep understanding of the resilience capability of nature and its ecosystems in calamity prone areas. The proposal aims to create a district in Coimbatore, consisting of plubic plazas, congregation spaces, lake view decks & promotes fishing activities.

NASA ANDC TROPHY 2016

NASA India - Shortlisted Top 50 - 2015 & 2016
The main aim of the brief was to highlight the social and psychological negatives in cities, and proposing altenate use-cases for isolated and unsafe public spaces, to make it safe and inclusive. The proposal sought ideas to rethink spaces below flyovers, in densely populated cities.

L I C E N S E S

COUNCIL OF ARCHITECTURE 2019 - ACTIVE

Licensed Architect - Registered to Council of Architecture, India
Registration Number - CA/2019/113651 - Active Since 2019.
Issued by the Ministry of Education, Government of India.
Valid License to Practice as an Architect in India.

LEED GREEN ASSOCIATE 2019 - INACTIVE

United States Green Building Council - LEED Licence
Credential ID - 0011150224 - Inactive Currently.
Issued in August 2019 - Valid through July 2021.
Knowledge in LEED Point System & Categories. The exam will be re-taken in future.

REVIT CERTIFICATION 2019 - ACTIVE

Revit Certification Course from USAM Certified Learning Centre, India
Credential ID - AP04030957646245216 72 - Issued in September 2019.
Detailed Training in Revit, BIM Workflow & Cloud Collaboration in a Month Long Course, covering aspects of Design, Documentation, Collaboration in Revit.

S T R E G N T H S

Design Thinking | Project Concept Ideation | Computational Design | Design Technology & Workflows Study, Analysis & Simulations for Sustainable Design | AEC Related AI-Tools | Design Optioneering Design Production Automation & Pipeline Setups (Presentations & Graphic Templates) | Creating Custom Clusters & Facade Libraries in Grasshopper | Design Graphics & Visualization | Participartory Design & Team Work | Team Building & Leadership Skills | Tutoring & Content Creation | People Interaction

D E S I G N S K I L L S

ADVANCED	INTERMEDIATE	BASIC	LEARNING
Rhinoceros 3D	*Autodesk Revit*	*Autodesk FlowDesign*	*Unreal Engine*
Grasshopper	*Autodesk Infraworks*	*Revit - Dynamo*	*Autodesk Maya*
SketchUp 3D	*Autodesk Forma*	*Pixologic ZBrush*	*Blender*
AutoCAD	*Ladybug & Tools (GH)*	*Fologram*	*GHPython*
Adobe Suite (Graphics)	*Rhino.Inside (GH)*	*VRay*	
Epic TwinMotion	*Speckle Connector*	*Veras & Lookx AI*	
Lumion	*Adobe Suite (Video Editing)*	*3D Printing*	
Enscape	*Mid-Journey AI*	*CNC Machining*	
MS Powerpoint	*MS Excel*		

E X T R A C U R R I C U L A R

GUINNESS WORLD RECORDS

Largest Ensemble of Electronic Music Keyboardists
On 27th November 2011, Isaimamani M.S.Martin, with his 109 students, created Guinness World Record by creating a Carnatic symphony on keyboard at the Music Academy.

MUSIC & CULTURE

Participated in a multitude of inter-school competitions, playing the electronic keyboard as part of the school band. Took part in the school's and college's annual day programs individually as well as as a group performance.

CANCER AWARENESS & DONATION CONCERT

Awareneess & Donation Concert for the Cancer Institute in Chennai, for three consequtive years; 2013, 2014, 2015. Key electronic musical keyboard player in a passionate team of musicians, involving orchestra instruments, choir, lead singers, pianists & percussionists.

URBAN & ARCHITECTURAL PHOTOGRAPHY

Interest in documentation of Urban Activities - The People & The Built. Manifested a small photography book called "Architectural Blues", capturing the fascinating buildings of Chennai. Participated and won a few college level photography competitions.

O B J E C T I V E

Given the nature of work and type of projects I had the opportunity to work on over the years, I had an unwavering commitment to develop environmentally conscious solutions has led to the development of impactful, sustainable, and data-driven designs for patient-centric healthcare facilities, this is in alignment to a growing demand for patient-centric healthcare facilities, especially in developing economies like India.

As an architect deeply passionate about healthcare design, I am particularly intrigued by the potential of developing a custom configurator that harnesses computational and generative design principles to streamline the design process for healthcare facilities. By integrating a modular planning system and sustainability principles, we can design efficient solutions that are site specific, functional, one that effectively reduce the carbon footprint, have a systemic approach to sustainability and promote a more conscious approach to healthcare design, benefitting the clients and users.